INDIAN RIVER
HYDROELECTRIC FEASIBILITY STUDY

FINAL REPORT
NOVEMBER 2009

Prepared For

CITY OF TENAKEE SPRINGS
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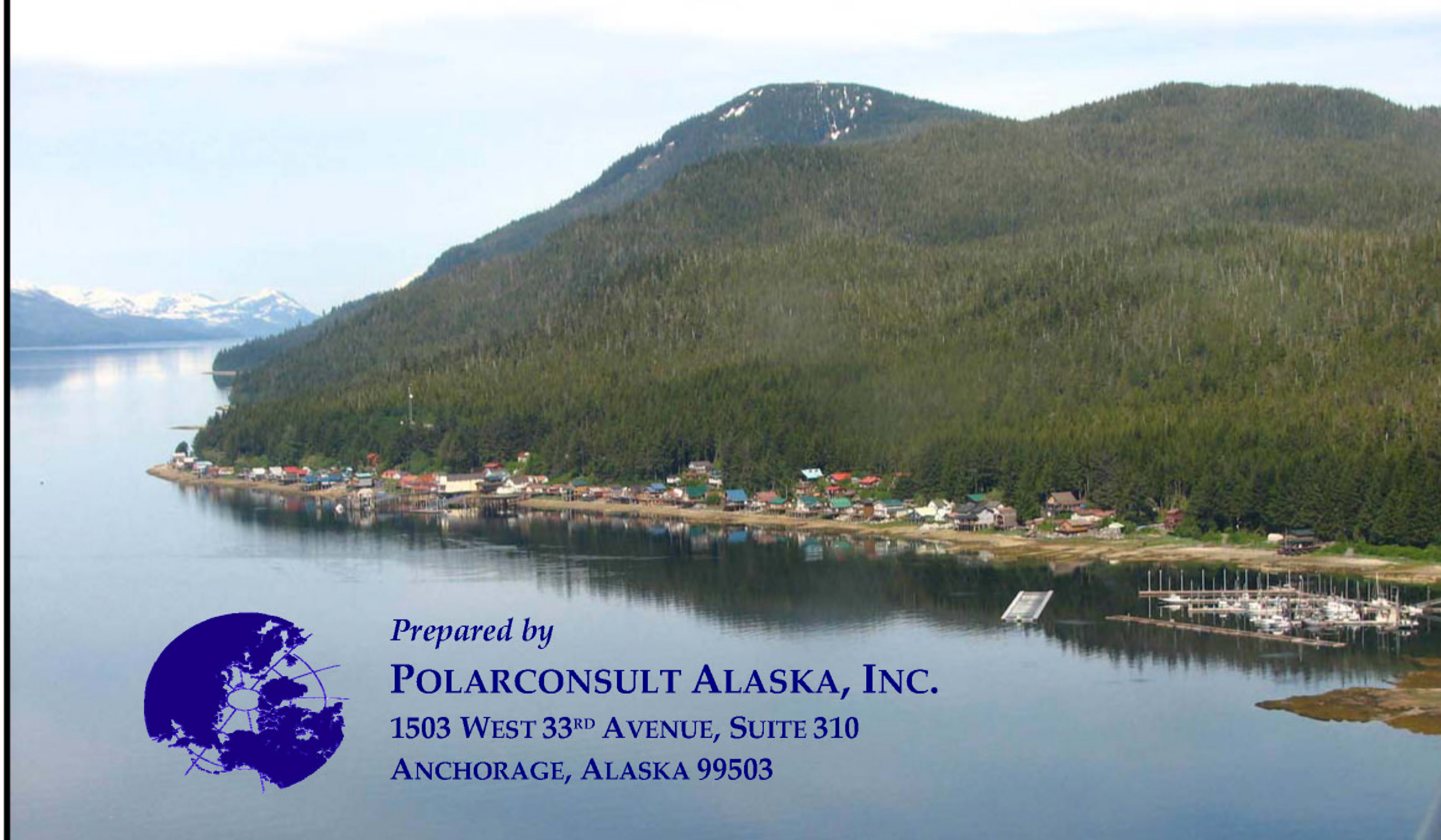

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THIS PROJECT WAS FINANCED BY THE DENALI COMMISSION AND ITS PARTNERS, THE ALASKA ENERGY AUTHORITY AND THE CITY OF TENAKEE SPRINGS.

EXECUTIVE SUMMARY

This study provides an analysis of the feasibility of constructing a hydroelectric project on Indian River to provide electricity for Tenakee Springs, Alaska. Of the seven project configurations analyzed, the recommended configuration is a 120-kW run-of-river hydroelectric project installed between the top of barrier falls #4 and the bottom of barrier falls #2 on Indian River. Technical and economic parameters for the recommended project are tabulated below:

TECHNICAL PARAMETERS	
Static Head	60 feet
Design Flow	41.0 cubic feet per second
Penstock	1,550' of 30" HDPE
Total Dynamic Head	50 feet
Turbine Type	Ossberger Cross-flow
Installed Capacity	120 kW
Capacity Factor	87.1%
Estimated Annual Energy Generation	839,000 kWh
Existing Utility Energy Generation	433,000 kWh
Transmission	4,500 feet of Three-phase 7.2kV buried cable
Estimated Direct Construction Cost	$1,752,000
Estimated Installed Cost	$2,590,000
Annual Displaced Diesel Fuel	44,400 gallons
Continuing Diesel Consumption for Electrical Generation	4,400 gallons
Benefit – Cost Ratio	1.33

The recommended project will meet 100 percent of the city's existing electrical demand about 85 to 90 percent of the time in an average year. During periods of low water flow in the mid-summer and winter, the diesels will sometimes need to operate to meet system load. The project offers a significant amount of excess energy that can be used by the community.

The recommended project is located on State of Alaska lands, with a portion of the power line located on city lands. FERC licensing is not required for the recommended project.

The recommended project can enhance the existing fish ladder at barrier falls #4 by increasing flow into the fish ladder during periods of low flow in Indian River and by improving access and bringing power and communications to the ladder to aid with fish monitoring activities.

The project's schedule hinges on the time required to obtain permission to use state land that the project will occupy. If this can be completed in a timely manner and construction funding can be secured, other project permits can be obtained and design completed in time for construction in 2011. Securing leases to state lands could delay construction to 2012 or 2013.

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ACRONYMS AND TERMINOLOGY

ADCED	Alaska Department of Community and Economic Development
ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AEA	Alaska Energy Authority
AEA / REG	Alaska Energy Authority Rural Energy Group
AEE	Alaska Energy and Engineering, Inc.
BLM	Bureau of Land Management
cfs	cubic feet per second
coanda effect	The tendency of a fluid jet to stay attached to a smoothly convex solid obstruction. A common example is the way a stream of water, as from a faucet, will wrap around a cylindrical object held under the faucet (such as the barrel of a drinking glass).
COE	U.S. Army Corps of Engineers
City	City of Tenakee Springs
CPCN	Certificate of Public Convenience and Necessity
Environmental attributes	The term environmental attributes is used by the green power industry to describe the desirable aspects of electricity that is generated by environmentally benign and/or renewable sources. Environmental attributes are tracked, marketed, bought and sold separately from the physical energy. Separating the environmental attributes enables customers on a given utility system to elect to buy sustainable or 'green' energy even if it is unavailable from their utility.
ft	foot, feet
FY	fiscal year
HDPE	high-density polyethylene

HDR	HDR, Inc.
in	inch, inches
kV	kilovolt, or 1,000 volts
kVA	kilovolt-amp
kW	kilowatt, or 1,000 watts. One kW is the power consumed by ten 100-watt incandescent light bulbs.
kWh	kilowatt-hour. The quantity of energy equal to one kilowatt (kW) expended for one hour.
LIDAR	Light Detection and Ranging
mi	mile, miles
MW	megawatt, or 1,000 kilowatts
NEC	National Electric Code
NESC	National Electric Safety Code
PCE	Power Cost Equalization Program
PDO	pacific decadal oscillation
Polarconsult	Polarconsult Alaska, Inc.
RCA	Regulatory Commission of Alaska
SDR	strength-dimension ratio.
TSEUD	Tenakee Springs Electric Utility Department
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
V	volt

1.0 INTRODUCTION

1.1 PROJECT AUTHORIZATION AND PURPOSE

In June 2008, the Denali Commission awarded the City of Tenakee Springs (City) funds for a feasibility study and conceptual design of a run-of-river hydroelectric project on Indian River The funds were awarded under the Commission's alternative energy project solicitation dated December 6, 2007. This award is managed by the Alaska Energy Authority's Rural Energy Group (AEA/REG).

In May 2009, the City of Tenakee Springs authorized Polarconsult Alaska, Inc. (Polarconsult) to complete a feasibility study and conceptual design for the hydroelectric project. This report is the Phase I deliverable (Feasibility Study) under this authorization, and presents a recommended development alternative for the hydroelectric resource.

With the City's approval, Polarconsult will complete a conceptual design and initiate permit processes for the preferred project alternative based upon the findings and recommendations presented in this report.

As described in Section 1.4, hydroelectric development of Indian River has been extensively studied in the past. In particular, a 1993 Polarconsult feasibility study identified the project as economical. Work completed for AEA in 2004 included limited review of the 1993 feasibility study, but an opinion on the project's feasibility was not given. Because significant time has passed since 1993, renewed evaluation of the feasibility of this project is appropriate.

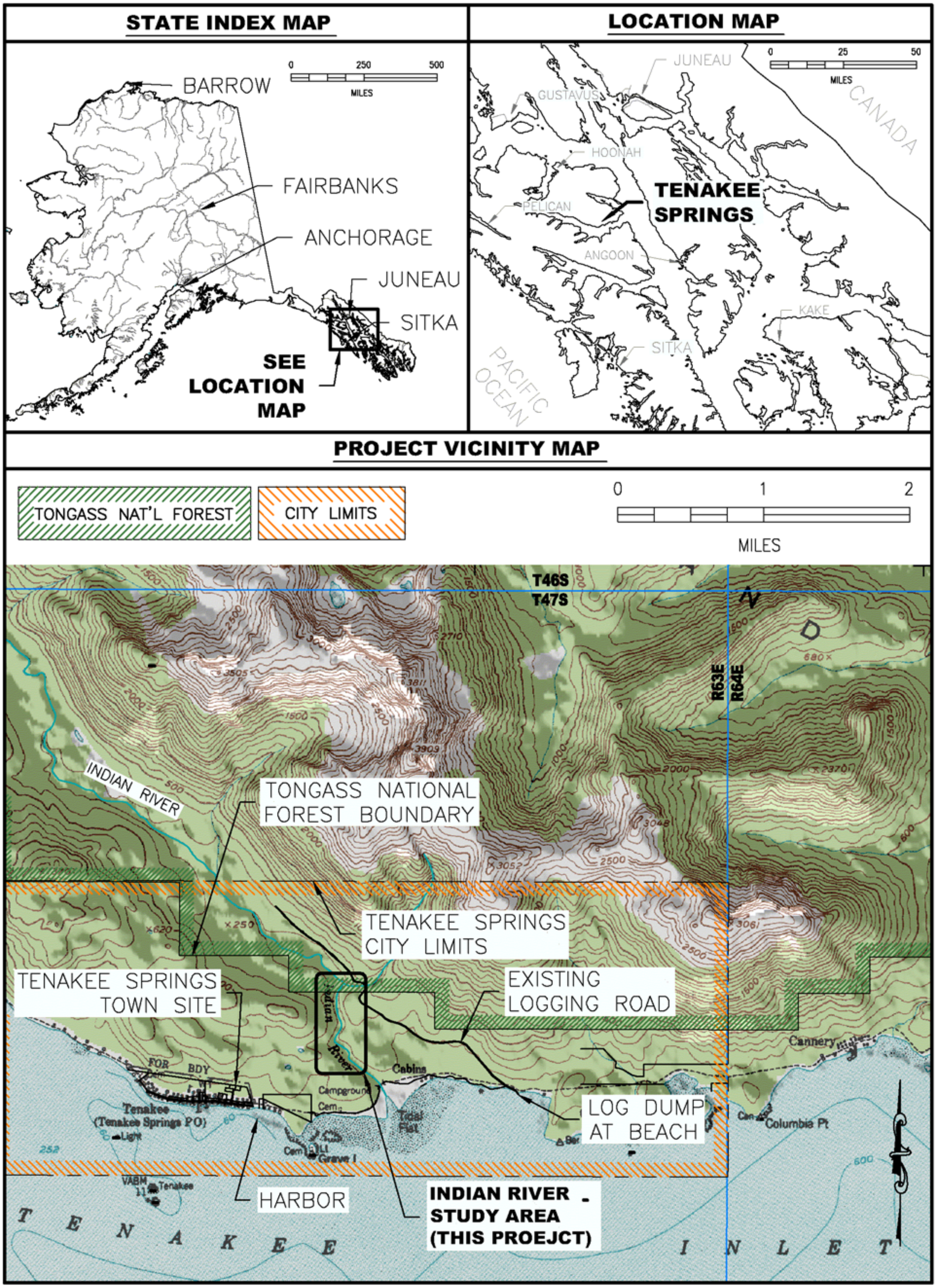
This feasibility study focuses on changes that occurred over the past 16 years which justify a different configuration than recommended in 1993. Project configuration, construction methods, resource reservations and availability, and community load requirements are all reviewed to arrive at a recommended project configuration and render an opinion on project feasibility.

Polarconsult engineers Joel Groves, PE and Mike Dahl, PE traveled to Tenakee Springs June 1 through 3, 2009 to collect data about the existing utility system and review the proposed hydroelectric site. All 5 barrier falls on Indian River were inspected, penstock routes and access routes were reviewed, and overland power line routes between the potential powerhouse sites and Tenakee Springs were walked.

1.2 PROPOSED ENERGY RESOURCE

The proposed energy resource is a run-of-river hydroelectric development on Indian River. The proposed energy resource is shown in Figure 1-1.

Figure 1-1: Project Overview and Location Map



1.3 COMMUNITY BACKGROUND

Tenakee Springs is located on the east side of Chichagof Island, on the north shore of Tenakee Inlet. It lies 45 miles southwest of Juneau and 50 miles northeast of Sitka. It lies at approximately 57.78° north latitude and 135.22° west longitude (Section 21, Township 47 south, Range 63 east, Copper River Meridian). The city encompasses 13.8 square miles of land and 5.3 square miles of marine waters. Tenakee Springs has a maritime climate with cool summers and mild winters. Normal summer temperatures range from 45 to 65 degrees and normal winter temperatures range from 25 to 40 degrees. The highest recorded temperature is 84 degrees, and the lowest recorded temperature is 3 degrees. Total precipitation averages 69 inches a year, with 62 inches of snow. Tenakee Springs is a second-class city and is not a federally recognized Native village. Tenakee Springs is located in the Sitka Recording District and the Chatham School District. [1]

Aerial view of Tenakee Springs, looking east-southeast. June 2009. Indian River is located less than a mile beyond the harbor (at the far end of town in this view).

[1] This community profile is compiled from background data in previous energy studies for Tenakee Springs and community data on the Alaska Department of Community and Economic Development (DCCED) website.

1.4 SUMMARY OF PREVIOUS STUDIES

Development of hydropower resources for Tenakee Springs has been under consideration for over 30 years. Previous studies have identified Indian River as the best resource for the community. These studies are briefly summarized below. Key features of Indian River and the various project configurations are presented in Figure 1-2.

1.4.1 1979 U.S. Army Corps of Engineers Study

Hydropower resources for Tenakee Springs were investigated as part of a regional reconnaissance study completed for the U.S. Army Corps of Engineers (COE) by CH_2M Hill in October 1979. The COE reconnaissance study identified the following potential projects:

1. A 700-kW run-of-river project at Indian River, about 1.1 miles east of Tenakee Springs.
2. A 325-kW run-of-river project at Harley Creek, about 4.5 miles east of Tenakee Springs

1.4.2 1984 U.S. Army Corps of Engineers Study

In 1984, the COE completed a more detailed feasibility study and environmental assessment of Indian River's hydropower potential. The COE selected a 265-kW run-of-river project built on the west side of Indian River between the head of barrier falls 5 and the toe of barrier falls 3 as the most cost-effective project. The COE estimated an installed cost for the project of $3.259 million (1984 $), and a benefit-cost ratio of 0.71. Based on these estimates, the COE did not recommend that the project be constructed.

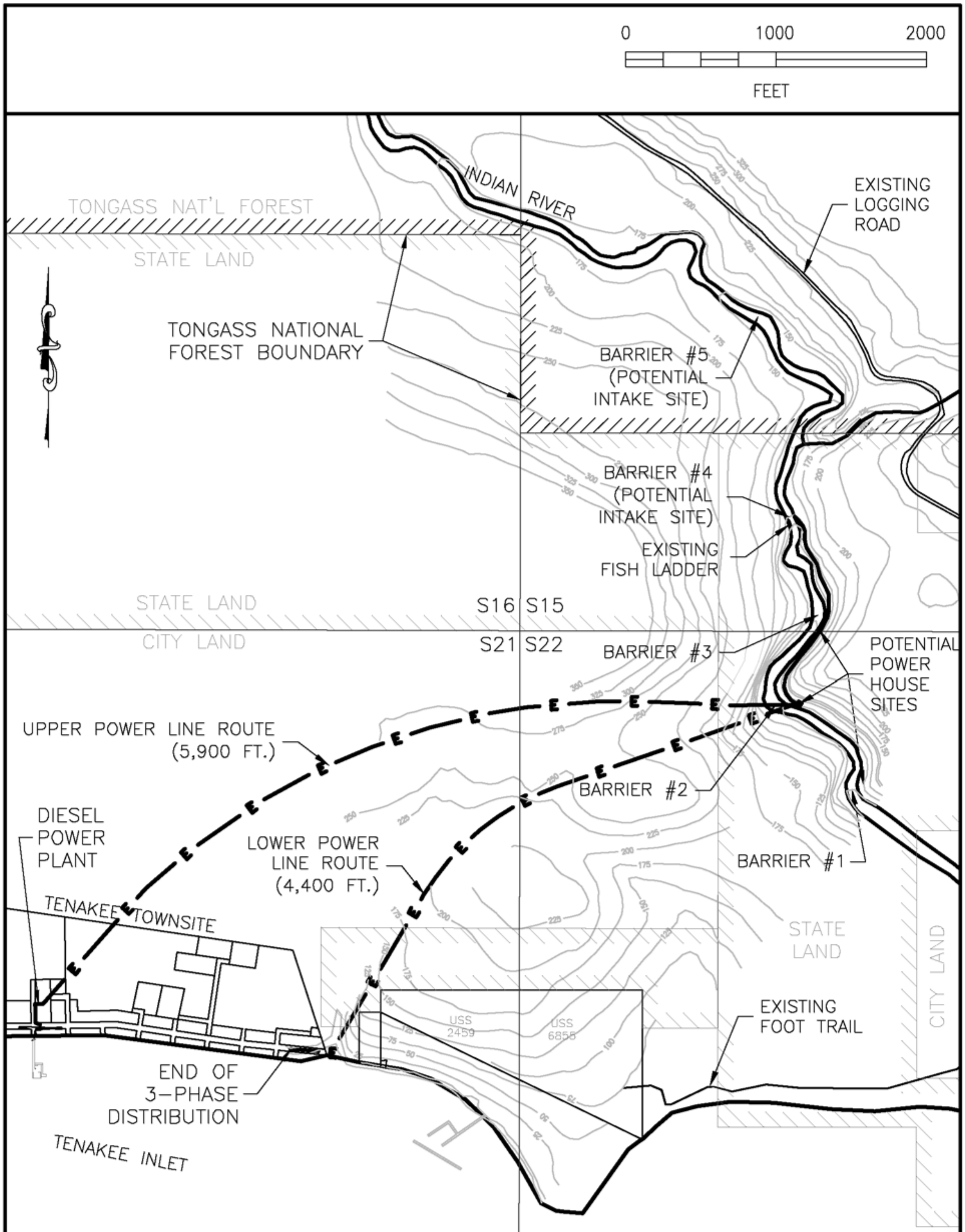
1.4.3 1993 Polarconsult Feasibility Study

In 1992, the City of Tenakee Springs retained Polarconsult to review the Indian River resource and determine if cost-effective development of the resource was feasible. Polarconsult devised a 125-kW project built on the east side of Indian River between the head of barrier falls 4 and the toe of barrier falls 2. This configuration reduced costs by avoiding the steeper cliffs along the west side of the river and by avoiding the need to obtain a FERC license for the project. Polarconsult estimated the direct construction cost of this project at $612,171 (1993 $).

1.4.4 2004 Alaska Energy and Engineering, Inc. Project Review

In 2004, Alaska Energy and Engineering, Inc. (AEE) retained HDR, Inc. (HDR) to conduct a review of the proposed Indian River project as part of electrical system upgrades completed for Tenakee Springs by the Alaska Energy Authority's Rural Energy Group (AEA/REG). AEE/HDR reviewed the 1993 Polarconsult project configuration, made a number of limited modifications to the proposed design and development plan, and generated an updated estimated direct construction cost of $1,400,000 and an estimated installed cost of $2,229,975 (2004 $). AEE/HDR did not offer an updated opinion of the project's feasibility.

Figure 1-2: Overview of Project Options



NOTES
1. PROPERTY LINES ARE INTENDED FOR INFORMATIONAL AND PLANNING PURPOSES ONLY.
2. CONTOUR DATA REPRODUCED FROM 1984 U.S. CORPS OF ENGINEERS STUDIES.

2.0 EXISTING ENERGY SYSTEM

2.1 COMMUNITY ENERGY PROFILE

Like most remote Alaska communities, Tenakee Springs has an isolated electrical system that does not have any transmission interconnections to other communities. Tenakee Springs relies 100 percent on diesel generation for electricity. Diesel fuel is imported via barge several times annually. Other local energy usage includes diesel and gasoline fuels for transportation, wood and fuel oil for space and water heating, and some use of propane gas for cooking.

Tenakee's new diesel powerplant. June 2009.

Tenakee's energy infrastructure is relatively new. A new bulk fuel facility and diesel power plant were constructed in 2006. The city's electrical distribution system was upgraded at the same time.

AEE completed a survey of the city’s total annual petroleum fuel consumption in 2004 for the bulk fuel upgrade Concept Design Report. AEE reported a total annual fuel usage (for electricity generation, transportation, marine sales, heating, etc.) of 141,800 gallons, and estimated future total fuel usage at 144,000 gallons annually.[2] Of this total, diesel fuel for power generation is approximately 32,500 gallons annually.

2.2 ELECTRIC UTILITY ORGANIZATION

Electrical service in Tenakee Springs is provided by the Tenakee Springs Electric Utility Department (TSEUD), which is owned and managed by the City of Tenakee Springs. The City holds Certificate of Public Convenience and Necessity (CPCN) No. 363, issued in 1986, authorizing it to operate a public utility providing electrical service in and around Tenakee Springs. Because the TSEUD is owned and managed by a political subdivision of the state, the Regulatory Commission of Alaska (RCA) has exempted the TSEUD from regulation as allowed by AS 42.05.711(b).

TSEUD participates in the State of Alaska’s Power Cost Equalization (PCE) program, which subsidizes electricity rates for residential and community facilities served by eligible Alaska utilities.

[2] Tenakee Springs Energy Infrastructure Upgrades Concept Design Report. AEE, Inc. August 2004.

2.3 GENERATION SYSTEM

Tenakee's power plant is located on a hillside above the center of the community. The plant has three generators controlled by four sections of switchgear. The switchgear is fully automatic with paralleling capability, and uses a programmable logic controller to match the generator(s) to system load. The plant generates at 480V three phase. The generation assets are generally in good condition - all major assets were installed new in 2006. Installed utility generation equipment in Tenakee Springs is listed in Table 2-1. [3]

Table 2-1: Existing Utility Generation Equipment

No.	Equipment	Prime Power (kW)	Commissioned Date	Designated Use
1	John Deere Engine / Marathon Generator	88 kW	2006	Normal peak
2	John Deere Engine / Marathon Generator	88 kW	2006	Normal peak
3	John Deere Engine / Marathon Generator	64 kW	2006	Nighttime load

2.4 ELECTRICAL DISTRIBUTION SYSTEM

The Tenakee Springs distribution system was upgraded in 2006. The system is a 7,200V grounded wye three-phase system without loop feed. The 7,200V system is entirely overhead on wooden poles. 480 V generated at the power plant is run down to the main street in above-ground conduit and stepped up to distribution voltage with a single 112.5 kVA pad-mount transformer. [3]

2.5 EXISTING AND PROJECTED FUTURE LOAD PROFILE

Community electrical demand is a function of population, electricity cost, and available income. Commercial, industrial, and transient loads such as the harbor can also be major factors in total system demand.

Tenakee's population, listed in Table 2-2, has fluctuated over the past century between 86 and 210. In recent decades, the population has varied between 90 and 120. The long-term population trend appears stable.

[3] Tenakee Springs Power System Upgrade Record Drawings Sheet E-2, AEE, Inc., 2007.

Table 2-2: Tenakee Springs Population Data

Year	Population
1909	126
1920	174
1929	210
1939	188
1950	140
1960	109
1970	86
1980	138
1990	94
1992	123
2000	104
2004	105
2008	99
Future	90 - 120

Median household income in Tenakee Springs over the past several years is presented in Table 2-3. Household income in Tenakee Springs has been increasing relative to state and national income over the past several years. As is typical in remote Alaskan communities, median household income does not reflect the fact that many residents supplement their incomes by subsistence-type activities such as gathering food and resources from the local environment.

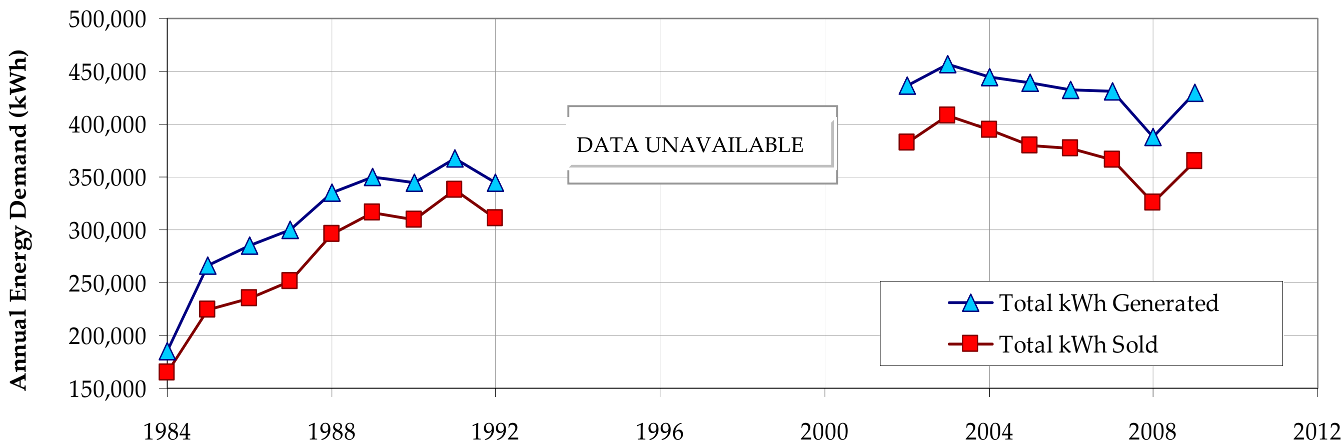
Table 2-3: Comparative Median Household Incomes

Population	1990	2000	2006-07
Tenakee Springs Median Household Income as percentage of Alaska Median Household Income	44%	64%	72%
Tenakee Springs	$18,125	$33,125	$43,636
Alaska	$41,193	$51,571	$60,506
United States	$30,056	$41,994	$49,901

Data compiled from Alaska Department of Labor and U.S. Census Bureau. Values not adjusted for inflation.

Total system electrical demand over the past several years is presented in Figure 2-1 and Table 2-4. System demand has increased 20 to 30 percent since the 1993 feasibility study and in recent years has been in the range of 400,000 to 450,000 kWh generated annually. Total generation has been declining very slightly since FY 2003, which can be attributed to a combination of new, more efficient generation equipment, distribution system upgrades in 2006, and consumer conservation measures due to cost increases since 2002. If electricity is available at a stable price from a hydro plant, it is probable that system demand will increase back to 2003 – 2005 levels.

Figure 2-1: Recent Electric System Demand



Note: Data is for PCE program fiscal years (July 1 through June 30).

Table 2-4: Past and Recent Electric System Statistics

	FY 84	FY 92	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09
KWh generated	182,703	344,956	436,660	456,500	444,960	439,360	432,480	431,740	387,311	430,200
KWh sold	165,024	311,094	382,049	407,537	394,727	380,375	377,449	365,767	325,532	364,831
Fuel Price	$1.25	$1.18	$1.41	$1.54	$1.71	$2.73	$2.06	$3.30	$3.60	$4.30
Fuel Used	27,728	31,042	35,510	36,280	36,239	35,192	34,894	33,125	30,542	32,587
Total Fuel Cost	$34,750	$36,625	$50,152	$55,815	$61,920	$96,129	$122,283	$109,150	$110,045	$140,854
Total Non-Fuel Cost	$14,654	$57,547	$41,977	$51,553	$56,936	$47,778	$48,983	$62,312	$46,456	$64,300
Total Power Production Cost	$49,704	$93,830	$92,129	$107,368	$118,856	$143,907	$171,266	$171,462	$156,501	$205,154
Power Cost per kWh	$0.299	$0.303	$0.241	$0.263	$0.301	$0.378	$0.454	$0.469	$0.481	$0.562
System Losses	10.8%	9.8%	12.5%	10.7%	11.3%	13.4%	12.7%	15.3%	16.0%	15.2%
Efficiency (kWh/gal)	6.6	11.1	12.3	12.6	12.3	12.5	12.4	13.0	12.7	13.2

FY 1984 and 1992 data is from the 1993 Polarconsult study. FY 2002 – 2009 data is from PCE annual reports and program database, with supplemental information for FY 2006 from TSEUD.

2.6 PLANNED UPGRADES

The bulk fuel, electrical generation, and distribution systems have all been recently upgraded. No additional upgrades are planned.

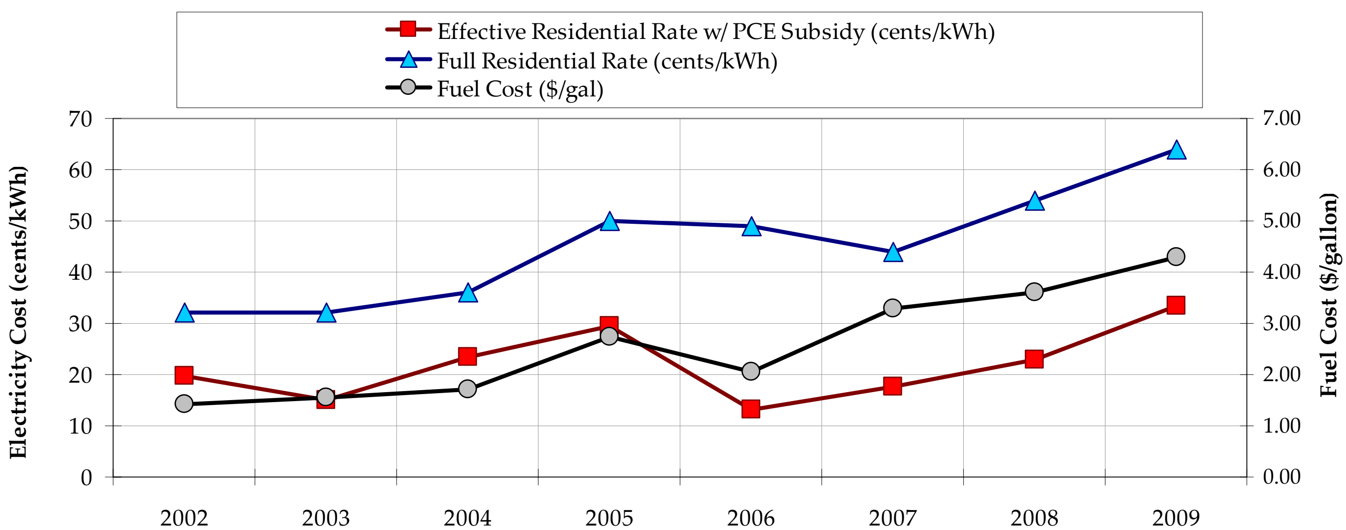
2.7 ENERGY MARKET

Energy from a local hydroelectric project would be fed into the TSEUD system to offset the need for diesel power generation. Also, the hydroelectric project would often generate energy in excess of electrical demand, which would be available to offset other energy consumption such as space heating or water heating. Supplying discretionary commercial/industrial loads, such as an ice plant to support local commercial fisheries, is also possible.

The cost of electricity for residential and community accounts is reduced by the Power Cost Equalization program. Subject to authorized annual state funding, this program partially subsidizes residential energy usage up to 500 kWh monthly. Households pay the full rate for consumption above 500 kWh monthly. Fuel costs have increased 317% from 2002 to 2009, and unsubsidized residential energy rates have increased 200%. PCE-subsidized residential energy rates have increased 169% from 2002 to 2009. Past electricity costs in Tenakee Springs are presented in Figure 2-2.

The primary direct economic values of the hydro project are (1) reduced expenditures on diesel fuel and (2) additional affordable energy available for the community. These amounts can be estimated for a given hydroelectric project and used to determine the value of the hydro. Analysis of these values is presented in Section 5.0.

Figure 2-2: Past Fuel and Electricity Costs



Note: Data is for PCE program fiscal years (July 1 through June 30).

3.0 PROPOSED ENERGY RESOURCES

3.1 RESOURCE DESCRIPTION

Indian River is located approximately one mile east of Tenakee Springs. Indian River has a series of 5 barrier falls occurring between river miles 0.6 and 1.3 above tidewater. The gross head over these five barriers is 100 feet. The mean annual flow in Indian River through these barriers is about 137 cfs. Extreme minimum flows of down to 8 cfs can occur during late summer dry spells (July – August) and the winter months (December – February).

Below barrier 5, Indian River is incised into a canyon about 50 to 100 feet deep. The canyon walls are generally steeper along the west bank (the Tenakee Springs side), and less steep along the east bank, although rock outcroppings are common along both banks through this canyon.

Recommended development of Indian River's hydropower potential is with a run-of-river hydroelectric project built along the east side of the river from the top of barrier 4 to the bottom of barrier 2.

3.2 HYDROLOGY

3.2.1 Available Hydrology Data

Discharge on the Indian River was measured by the USGS (gauges #15107910 and #15107920) from 10/1/1975 through 9/30/1982, providing seven years of discharge data. While the seven years of discharge data for Indian River is useful to project performance of a hydroelectric project on Indian River, the confidence of these projections can be increased by expanding this dataset.

Synthesizing discharge data for Indian River beyond the seven years of actual data is best achieved by correlating Indian River discharge to that of other basins with longer periods of record. Synthetic data can also be generated using precipitation data. However, correlating discharge from comparable basins typically yields superior results if suitable data exists – as it does for Indian River.

The USGS has recorded discharge at numerous streams in the vicinity of Indian River. Polarconsult reviewed USGS gauge data for streams along the northern panhandle for potential correlation candidates in order to extend the period of record for Indian River. Gauges at Kadashan River, Pavlof River, and Tonalite Creek met these criteria. Kadashan River and Tonalite Creek are located directly across Tenakee Inlet from the Indian River basin. The Pavlof River basin is located directly east of and adjacent to the Indian River basin. USGS data and characteristics of these basins are summarized in Table 3-1. The basins are shown in Figure 3-1.

Table 3-1: Summary of Hydrology Basins

Location	USGS Gauge ID	Basin Size (sq mi)	Site Elevation (ft)	Site Latitude (DMS)	Site Longitude (DMS)	Record Begin Date	Record End Date	Daily Records
Indian River (falls 5 intake site)	-	20.7	140	57°47'18"	135°11'33"	-	-	-
Indian River (falls 4 intake site)	-	22.1	110	57°47'12"	135°11'38"	-	-	-
Indian River at falls	15107910	3.02	490	57°51'58"	135°19'31"	7/18/79	9/30/81	806
Indian River	15107920	12.9	330	57°49'50"	135°16'00"	10/1/75	9/30/82	2,556
Kadashan River	15107000	37.7	3	57°41'43"	135°12'59"	9/1/64	9/30/79	5,507
Tonalite Creek	15106980	14.5	50	57°40'42"	135°13'17"	6/1/68	9/30/88	7,426
Pavlof River	15108000	24.3	20	57°50'30"	135°02'09"	6/1/57	9/30/81	8,888
Green's Creek	15101500	22.8	50	58°05'18"	134°44'49"	10/1/78	9/30/92	5,114
Green's Creek	15101490	8.62	-	58°05'00"	134°37'54"	8/18/89	9/30/08	6,894

3.2.2 Analysis of Hydrology Data

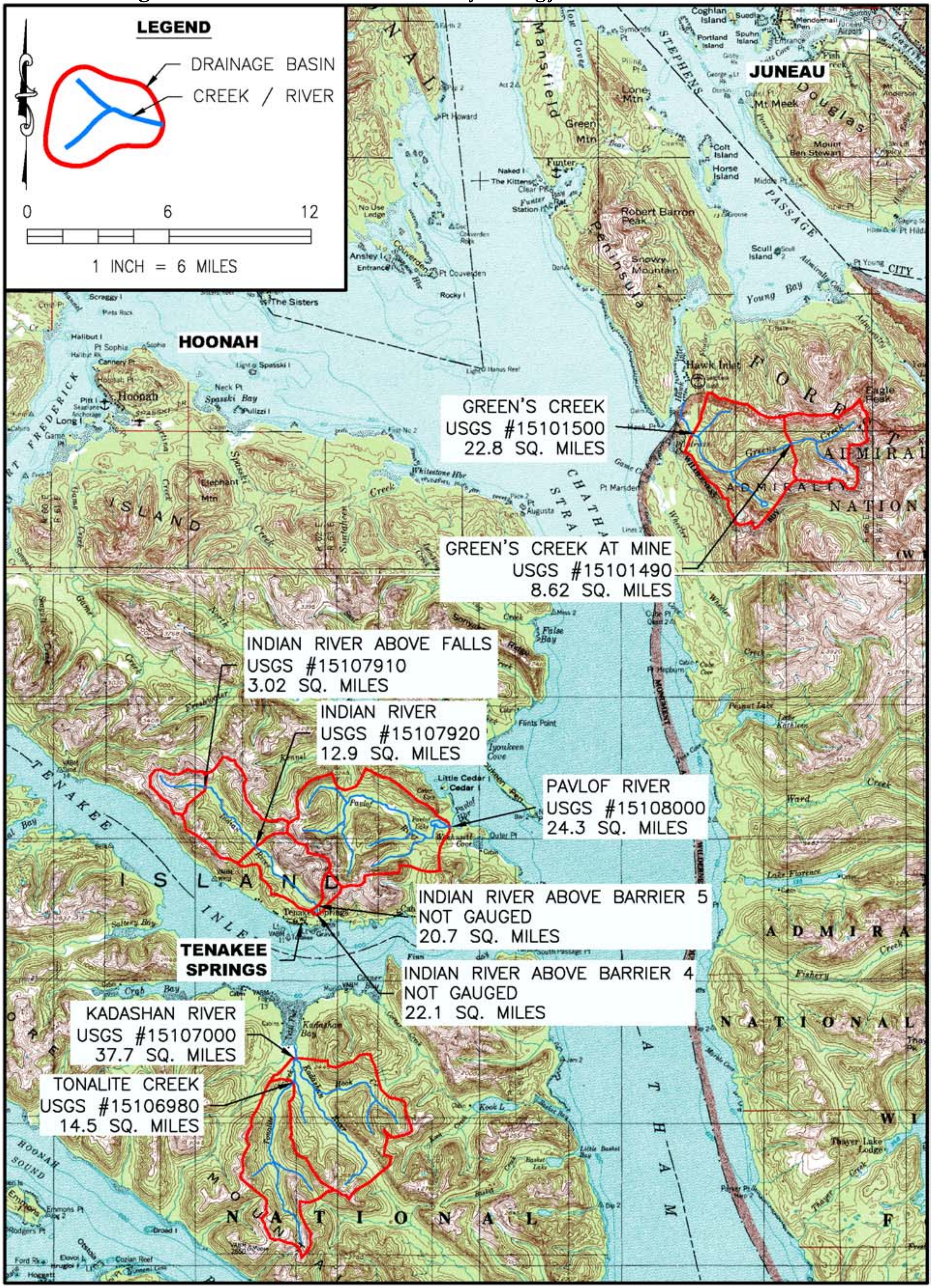
A correlation analysis was performed on the daily discharge records between Indian River at gauge #15107920 and the three nearby basins (Kadashan River, Tonalite Creek, and Pavlof River) for their common periods of record. All three basins produced good correlation coefficients, which are summarized in Table 3-2. Correlation coefficients were also calculated for the two Indian River data sets and for Green's Creek, located about 30 miles northeast of Indian River.

Table 3-2: Basin Hydrology Correlation Results

Correlation Basin (Correlation with Indian River)	USGS Gauge ID	Correlation Coefficient	Begin of Record Overlap	End of Record Overlap	Count of Correlated Records
Indian River at falls	15107910	0.946	7/18/79	9/30/81	805
Kadashan River	15107000	0.834	10/1/75	9/30/79	1,460
Tonalite Creek	15106980	0.846	10/1/75	9/30/82	2,556
Pavlof River	15108000	0.851	10/1/75	9/30/81	2,191
Green's Creek	15101500	0.785	10/1/78	9/30/82	1,460
Green's Creek [1]	15101490	0.731	8/18/89	9/30/92	1,139

Note 1: Correlation results are between Green's Creek gauges #15101500 and #15101490.

Figure 3-1: Location of Relevant Hydrology Basins near Indian River



The correlation coefficient for the two gauges on the Indian River is very high at 0.946 - perfectly correlated basins would have a coefficient of 1.00. For comparison, the two gauges on Green's Creek are also both located in the same drainage, but have a correlation coefficient of only 0.731.

With these correlation results, the seven years of data for Indian River (October 1975 to September 1982) can be extended back to June 1957 via the Pavlof River dataset and forward to September 1988 via the Tonalite Creek dataset for a synthetic record spanning 31 years.

Second-order polynomial functions were used to separately fit each of the three nearby basin datasets to the Indian River dataset for the common periods of record. These functions were fitted to provide greatest accuracy in the 0 to 50 cfs range (on Indian River), and reasonable accuracy at higher flows. These fitted equations were then used to generate synthetic Indian River flows from recorded flows in the nearby basins. This approach provides a model with greater accuracy at lower flows, which provides more accurate modeling of energy generation and the impacts of in-stream flow reservations. The resulting synthetic flows were scaled by basin area from the Indian River gauge to the various hydro project intake sites. The fitted equations for the hydrology model are presented in Table 3-3.

Because the data sets for the three nearby basins have overlapping periods of record, there are times when synthesized discharge data from multiple basins are available. Different approaches for selecting between these models were evaluated, and averaging all of the model outputs was found to best predict actual discharge in Indian River. The resulting model was compared with the seven years of actual discharge data with Indian River, and had a correlation coefficient of 0.865.

Table 3-3: Fitted Equations for Indian River Discharge Model

USGS Gauge Dataset	Fitted 2nd –Order Polynomial Equation
Pavlof River	$Q_I = -.000075\ Q_P^2 + 0.44\ Q_P + 0.31$
Tonalite Creek	$Q_I = -.00040\ Q_T^2 + 1.00\ Q_T - 5.00$
Kadashan River	$Q_I = -.00005\ Q_K^2 + 0.24\ Q_K + 40.0$

Q_I = Modeled flow in Indian River (at USGS gauge #15107920).

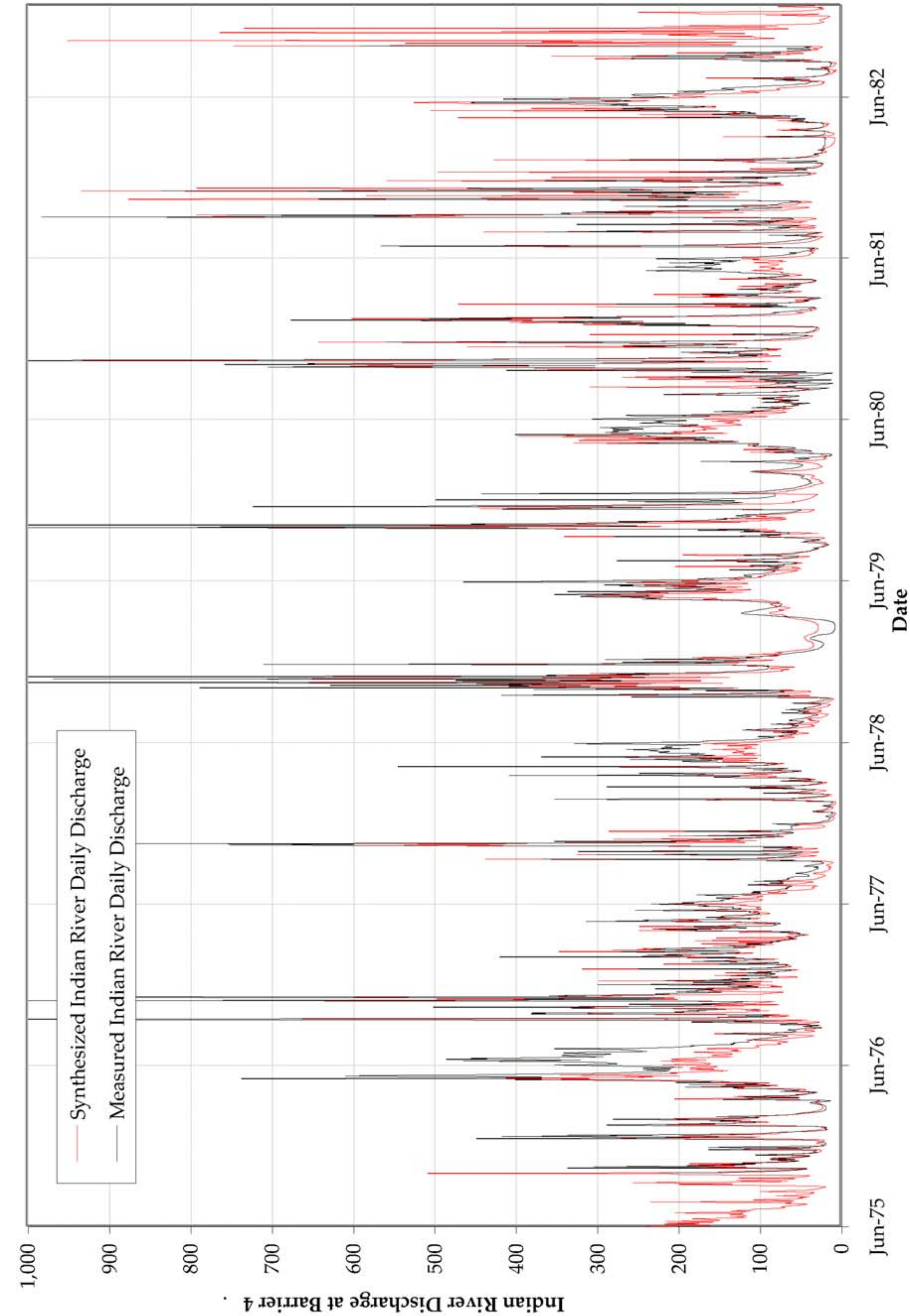
Q_K = Recorded flow in Kadashan River by USGS.

Q_T = Recorded flow in Tonalite Creek by USGS.

Q_P = Recorded flow in Pavlof River by USGS.

The resulting daily discharge model data is compared with measured daily flows in Figure 3-2.

Figure 3-2: Actual and Model Daily Discharge for Indian River

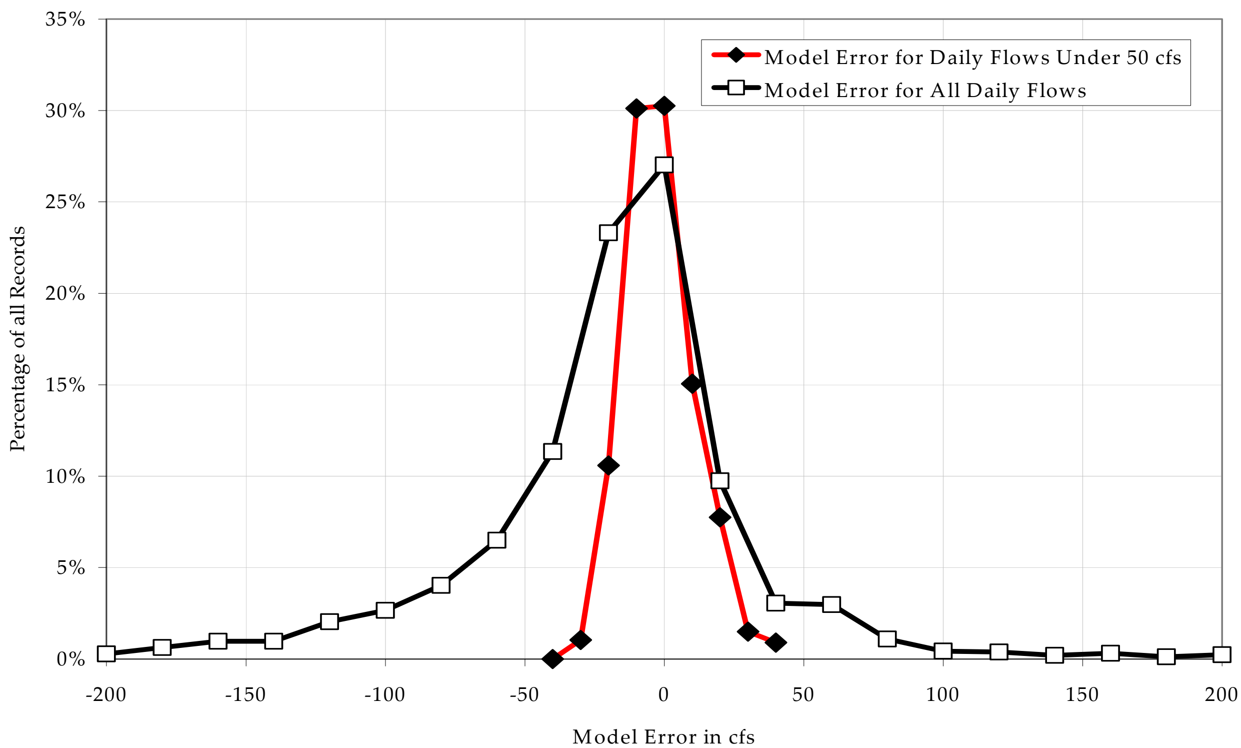


To evaluate the accuracy of the synthetic discharge data, the error between the synthetic daily discharge and actual daily discharge for the Indian River was reviewed for the October 1975 through September 1982 period, and is plotted on Figure 3-3. Observations from Figure 3-3:

- At flows less than 50 cfs, the model was accurate to within +/-10 cfs 75% of the time.
- At flows less than 50 cfs, the model is about equally likely to over or under estimate discharge, so over long periods of time, model errors will tend to time-shift hydro (or diesel) energy production rather than over- or under-forecast energy production.
- The model has larger errors over the entire range of discharge. Because the recommended project flow combined with fish ladder flows totals only 51 cfs, the accuracy of the model at higher flows is relatively unimportant for economic analysis purposes.

Thus, the accuracy of the hydrology model is considered adequate for economic modeling of the hydroelectric project.

Figure 3-3: Error Distribution for Indian River Discharge Model



3.2.3 In-Stream Flow Requirements

All of the considered project configurations would have the potential to dewater the USFS fish ladder at barrier 4. Excessive dewatering of the fish ladder would impair its functionality, which is not desired. To maintain functionality of the fish ladder, minimum flows need to be maintained in Indian River at the top of the ladder during fish migration seasons.

USFS personnel measured flows at the top of the ladder in August 2004 to determine the minimum flow requirement for the ladder. They visited at a period of low flow – measured flow above the ladder was 9.0 cfs, which has a greater than 98% exceedance level for the Indian River in August. Based on their field measurements, a minimum flow requirement for the ladder of 10 cfs was determined. [4]

Review of photographs in the 2004 USFS trip report indicates that at 9 cfs, a significant amount of water was not entering the ladder and still flowing down the natural falls. This suggests that the fish ladder needs less than 10 cfs to function, but it takes 10 cfs of flow in Indian River to deliver sufficient water to the fish ladder inlet with the existing inlet configuration. If the hydro intake improves existing inlet conditions to preferentially direct low flows to the fish ladder, it may be possible to both improve low-flow fish passage and reduce the in-stream flow reservation. This would benefit both fish passage and hydropower generation potential. This possibility warrants investigation in the permitting and design phase of the project.

As part of HDR's 2004 review of the project, Ken Coffin with USFS was contacted regarding fish requirements on Indian River. Based on this conversation, the critical season for fish migration via the fish ladder is late August through early December. [5]

3.2.4 Maximum Probable Flood

The 1984 COE study of Indian River included analysis of the maximum probable flood for Indian River. This analysis is considered adequate for feasibility assessment purposes. The maximum probable flood, with a 100-year expected recurrence interval, is 5,670 cfs.

3.2.5 Review of Climate Effects on Hydrology

Long term climate trends can affect the amount of discharge in Indian River and therefore the amount of energy that a hydro project can generate. Two climate fluctuation phenomena are of interest for this project:

1. The Pacific Decadal Oscillation (PDO). [6] The PDO has been demonstrated to measurably affect the energy generation potential of Alaska run-of-river hydropower resources. [7]

2. Global warming climate change.

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[4] USFS Trip Report, Martin Becker and Dan Kelliher, USFS Sitka Supervisor's Office, August 24, 2004.

[5] HDR Final Project Memo on Indian River Hydroelectric Project, August 4, 2004.

[6] The PDO is a climate fluctuation phenomenon similar to the 'El Nino / La Nina' oscillations in the tropical and southern parts of the Pacific Ocean. The PDO and its effects on Alaska's climate are discussed at http://jisao.washington.edu/pdo/.

[7] Polarconsult has evaluated other Alaska hydropower resources for PDO effects. Annual average energy generation for run-of-river resources in southcentral Alaska has been found to vary by about 5% due to the PDO. Other long-term climate trends have not been evident in Polarconsult's analyses.

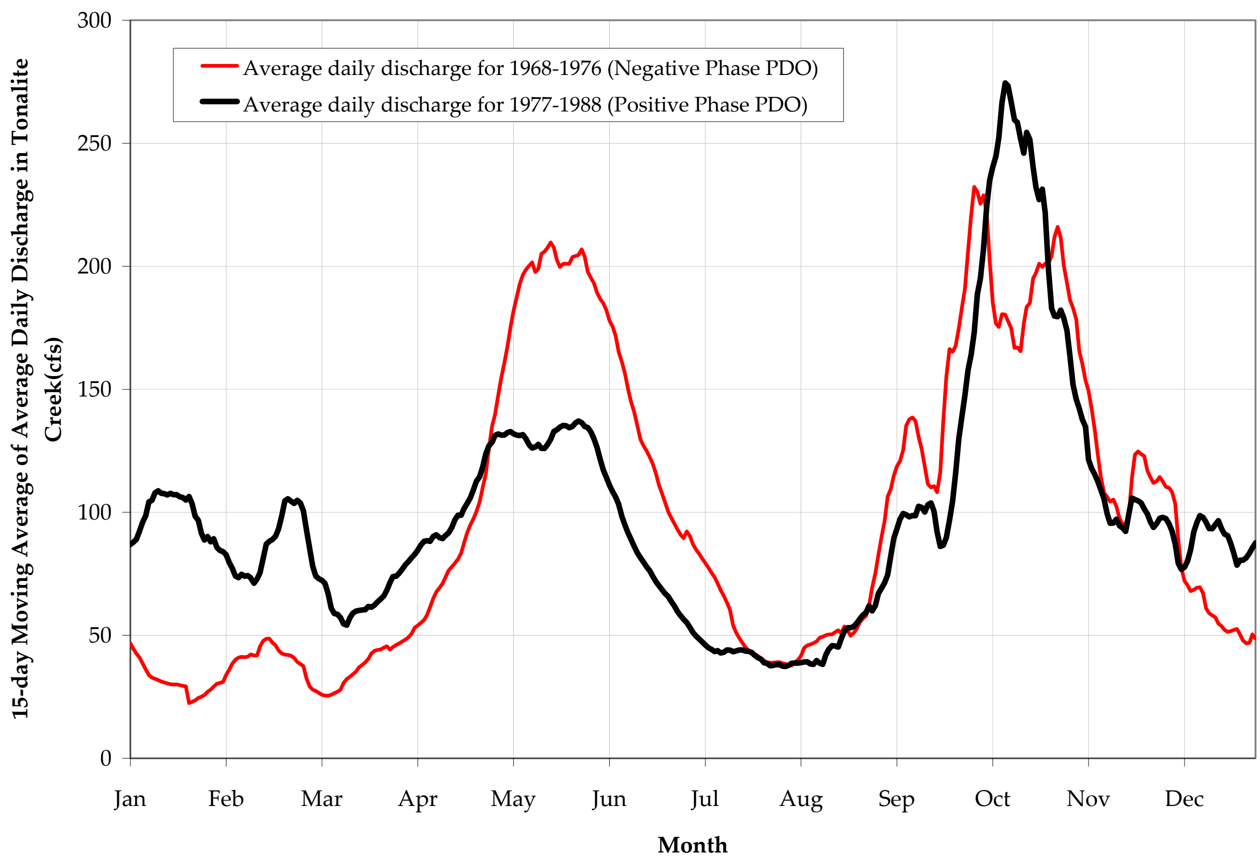
3.2.5.1 Analysis of Effects from PDO

The synthesized 31-year discharge record for Indian River is derived from different basin discharge data collected over different time intervals. Because of this, caution must be used in interpreting perceived long-term climate effects from this dataset. Detected artifacts can be attributed to either climate trends or underlying basin-discharge differences.

Analysis of energy generation calculated using the synthetic Indian River discharge dataset reveals that annual energy generation is about 5.5% higher on average during the positive-phase PDO than it is during the negative-phase PDO. This 5.5% fluctuation is not a large enough effect to significant impact the feasibility of the hydro project.

The 20-year Tonalite Creek hydrology dataset spans the 1976-77 PDO shift, and is therefore the best single discharge record to evaluate PDO effects on basin discharges near Tenakee Springs. Review of this dataset shows that winter discharge is significantly higher during the positive-phase PDO, suggesting that the 5.5% annual energy variation observed from analysis of the synthetic Indian River hydrology may be due to the PDO.

Figure 3-4: Average Tonalite Creek Discharge During Negative and Positive Phase PDO



3.2.5.2 *Analysis of Affects from Global Warming*

Analysis of energy generation calculated using the synthetic Indian River discharge dataset reveals a very slight increase in annual energy generation over the 31-year period. The effect, if real and not an artifact of the synthesized data, is equal to about a 0.07% annual increase which is insignificant in terms of project feasibility.

3.3 GEOTECHNICAL

The project area is recently glaciated, and is characterized by thin organic soils over a mantle of inorganic granular glacial deposits of varying depths. Bedrock is exposed in many areas, and is likely shallow over much of the project area.

View of rock outcrop looking downstream from proposed intake location at Falls 4.

Exposed bedrock is evident at the potential intake sites at barriers 4 and 5. Occasional bedrock outcrops are visible along the penstock route along the east bank of the river. According to USFS data, these rock outcrops are kennel creek limestones of Devonian and Silurian age. [8]

Depressions or level areas in the terrain, in particular along the power line routes, are generally unforested wetlands with a significant layer of organic soil. Other level areas, such as on the east side of Indian River between the logging road and canyon rim, are mature old-growth conifer forest with a relatively dry and open understory.

Exposed bedrock at the recommended intake site at barrier 4 will facilitate construction of an intake structure. The powerhouse site, located at the toe of the canyon sideslopes, may be complicated by the presence of unconsolidated deposits. Bedrock should be shallow at these areas and finding a good powerhouse site founded on rock is likely.

The canyon walls on the west side of Indian River are very steep and in some areas consist of unvegetated active slide zones. Routing a penstock on this side of the canyon would require major civil works that would be prohibitively expensive to both construct and maintain.

[8] Figure 1-2 and accompanying text, Indian River Watershed Analysis, Sitka Ranger District, USFS, 1996.

The canyon walls on the east side of Indian River are less steep and are generally vegetated. Construction of a penstock down this side is feasible, although this penstock corridor still presents the most significant geotechnical challenges for the project. Some blasting of rock outcrops will likely be necessary. In other areas, construction must either consist of a relatively high impact bench, which has the potential to destabilize the side slopes, or a more minimalist structure, such as a timber structure supporting a penstock, which can be keyed into bedrock and keep most of the vegetation in the canyon intact. Careful design and construction of the penstock will be necessary to control costs and prevent undesirable mass wasting or soil slides.

3.4 PROJECT LANDS

Land ownership in the project vicinity is indicated on Figure 1-2. With the exception of a city-owned campground site near the mouth of Indian River, the lower reach of Indian River from its mouth to the Tongass National Forest boundary is located on state land. The USFS holds a lease for the fish ladder at barrier 4. There is also a public-access easement from the logging road to the fish ladder site (ADL 106204). The Tongass National Forest boundary runs east-west between barrier 4 and barrier 5. Land north of this line are part of the Tongass National Forest.

For the recommended project, with an intake above barrier 4 and powerhouse below barrier 2, the project works and access routes will be located on state land. Projects with an intake at barrier 5 would be located partially on federal (U.S. Forest Service) land.

Power line routes from the hydro powerhouse to Tenakee Springs would cross state land near Indian River and near Tenakee Springs. In between, they would be located on city land. There are existing city land or platted streets that provide access for the power line to connect from the uplands behind town to the existing distribution system.

3.4.1 Site Control Requirements

Any hydroelectric project will require clear title to the land it occupies. This includes the land associated with the intake/diversion structure footprint, penstock alignment, powerhouse and tailrace footprint, transmission line alignment, and access trails or roads. Title to this land can take a variety of forms. Some typical methods are listed below:

- Land transfer or purchase. The City approached USFS in 2002 regarding a potential land swap for a hydro project utilizing barrier 5, and USFS was not interested. The land along Indian River downstream of the current Tongass boundary was included in the State's conveyance to the City. However, the State retained title to this land for a variety of purposes as set forth in the 1981 settlement agreement between the City and the State. This settlement agreement anticipated a future hydroelectric project along Indian River, and indicated that the State's normal right-of-way procedures be used to secure title to land necessary for the project. The City could approach the State regarding a land swap for the project, or work with ADNR's procedures to lease the project lands. [9]

- Easements. Property rights for the project's linear features, such as access routes, power lines, and penstocks, can be secured by easements. For this project, access routes could occupy public-access easements (as already exist to the fish ladder at barrier 4), and the power line and penstock could occupy utility easements.

- Leases. If land purchase or transfer is not possible for the powerhouse and intake sites, these can be leased on a long term basis from the State of Alaska. ADNR has a non-competitive charitable-use lease process that TSEUD would likely use. [9] ADNR land leases have a maximum term of 55 years. Based on similar recent leases ADNR has completed, a lease term of 30 to 50 years is expected for this project.

[9] ADNR's land disposal (lease or sale) processes for public and charitable uses are described in AS 38.05.810.

4.0 PROPOSED PROJECT DESIGN

4.1 ANALYSIS OF PROJECT ALTERNATIVES

Five general project configurations along Indian River were considered:

- Top of barrier 4 to bottom of barrier 2
- Top of barrier 4 to bottom of barrier 1
- Top of barrier 5 to bottom of barrier 3
- Top of barrier 5 to bottom of barrier 2
- Top of barrier 5 to bottom of barrier 1

View of barrier 5 looking upstream (left)
View of barrier 4 and USFS fish ladder looking upstream (right)

Projects with an intake at barrier 5 would be located partially on USFS land, and would therefore require either a FERC license or a FERC license exemption. Projects with a powerhouse located below barrier 2 would dewater higher-grade habitat located between barrier 2 and barrier 1, and could therefore be subject to higher in-stream flow reservations.

Technical aspects of these four configurations are summarized in Table 4-1.

Table 4-1: Technical Summary of Project Alternatives

Parameter	Barrier 4 to 2	Barrier 4 to 1	Barrier 5 to 3	Barrier 5 to 2	Barrier 5 to 1
Gross Head (ft)	60	80	65	90	110
Design Flow (cfs)	41.0	31.0	38.0	27.0	20.5
Penstock	1,550' of 30" HDPE	2,500' of 28" HDPE	2,750' of 32" HDPE	3,350' of 28" HDPE	4,400' of 28" HDPE
Net Head (ft)	50	66	53	75	98
Turbine Type	Ossberger Cross-flow	Ossberger Cross-flow	Ossberger Cross-flow	Ossberger Cross-flow	Ossberger Cross-flow
Capacity (kW)	120	120	120	120	120
Capacity Factor (%) [1]	87.1%	90.3%	86.9%	90.1%	91.1%
FERC Licensing or Exemption Required	No	No	Yes	Yes	Yes
Higher In-Stream Flow requirement	No	Possible [2]	No	No	Possible [2]

1. Capacity factor is the amount of energy the project is expected to produce divided by the theoretical energy that could be produced if adequate water was available year-round. Calculations are based on the average model water year for Indian River with a 10 cfs year-round in-stream flow reservation for fish passage.
2. Maintaining fish habitat between barrier 2 and barrier 1 may require more than the 10 cfs minimum in-stream flows necessary for other project configurations.

4.2 RECOMMENDED PROJECT

4.2.1 Recommended Resource Development

Of the five resource configurations considered, the barrier 4 to barrier 2 project is recommended. All five projects have substantially similar energy generation potential, especially when measured against TSEUD's existing electrical demand. Most of the difference in generation potential is in how much excess energy the projects would produce. All five project configurations offer more total energy than TSEUD's total current annual generation.

Since the energy potential is about the same, the recommended project was selected based largely on cost. The three projects with an intake at barrier 5 would require a FERC license exemption, increasing pre-construction costs. The other projects each have significantly longer penstocks, which would increase construction costs relative to the recommended option.

4.2.2 Recommended Capacity

The best sized project to build at Indian River depends on the project cost and ability of the community to use the energy. For the relatively small projects considered at Indian River, cost does not vary much with installed capacity – the costs are similar if 60, 120 or 180 kW is installed. This is due to many of the project features being largely independent of capacity, such as:

- Access corridors
- Power and communications lines
- Permitting and design
- Intake structure
- Controls

Other cost items do vary with the size of the project, but they do not change dollar for dollar. For example, if the capacity is halved from 120 kW to 60 kW, the turbine cost does not drop in half, nor can the power house be half the size. Such cost items include:

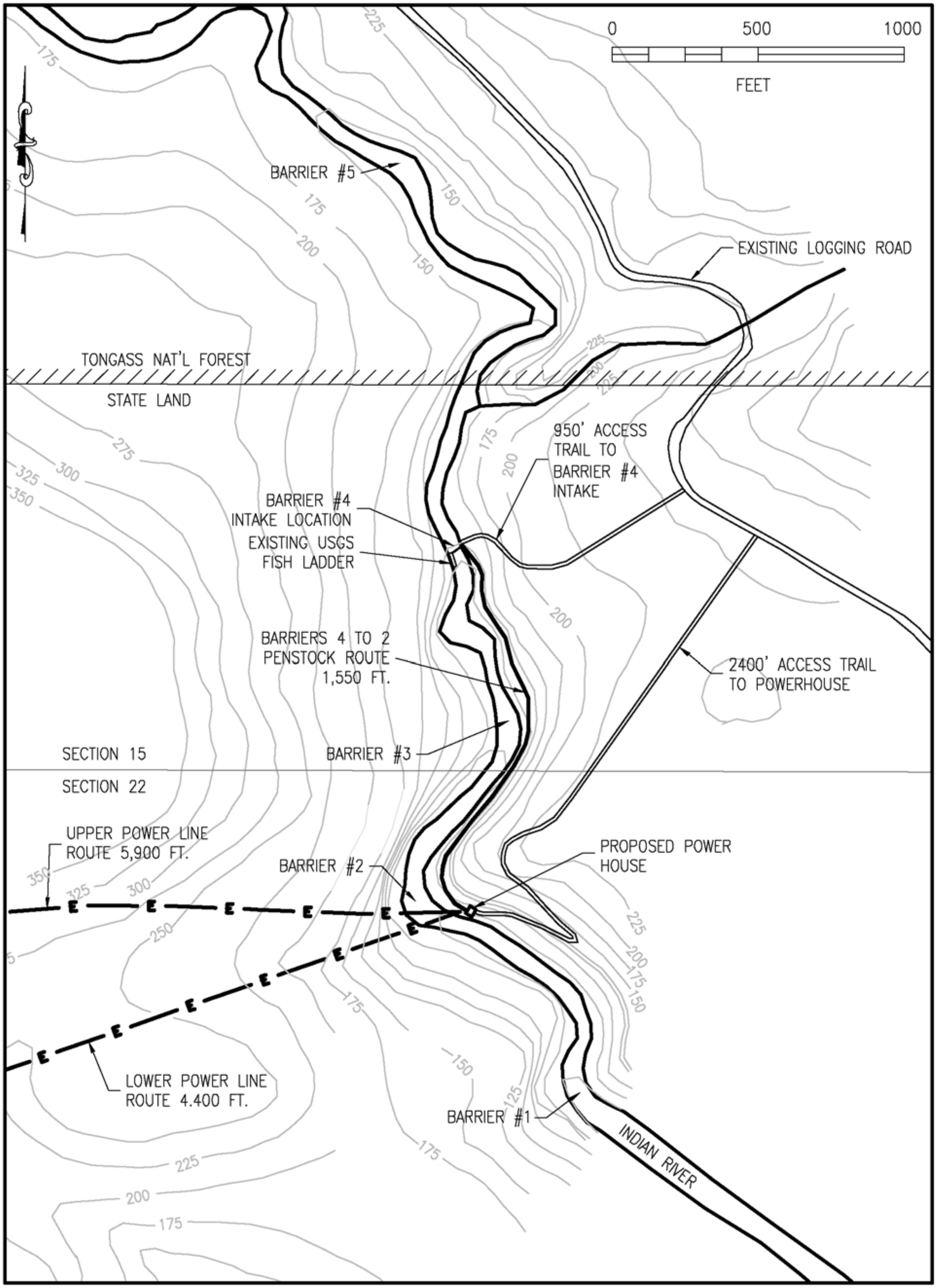
- Penstock
- Turbine / generator / switchgear
- Powerhouse

Construction of 60 kW and 180 kW projects at the recommended site were considered. The 60 kW option would only achieve a 10 to 20 percent installed cost savings relative to the recommended 120 kW project. This project would be unable to supply enough power to meet TSEUD's existing peaks, so diesels would have to run significantly more often, reducing the fuel savings. Also, this project would generate comparatively little excess energy for Tenakee – about 72,000 kWh annually, compared with 447,000 kWh of excess energy from the recommended 120 kW project.

A 180 kW project is estimated to be only 10 to 20 percent more costly than the recommended 120 kW project. Since crossflow turbines require at least 25 percent of their design flow to operate, this project actually meets slightly less of TSEUD's existing energy demand because the larger turbine is shut down more often during low flow periods. Thus, the value of the 180 kW project lies in the excess energy it offers to the community. If the community is unable to use all of this energy, the additional cost of the 180 kW project is not justified. If the utilization rate of excess energy drops from 90 percent for a 120 kW project to 80 percent for a 180 kW project, the larger project has a lower benefit – cost ratio (see section 5). Because it may be difficult for Tenakee Springs to absorb all of the energy from a 180 kW project, the 120 kW project is recommended.

The project layout is shown in Figure 4-1.

Figure 4-1: Recommended Project Layout



4.3 ANNUAL ENERGY PRODUCTION

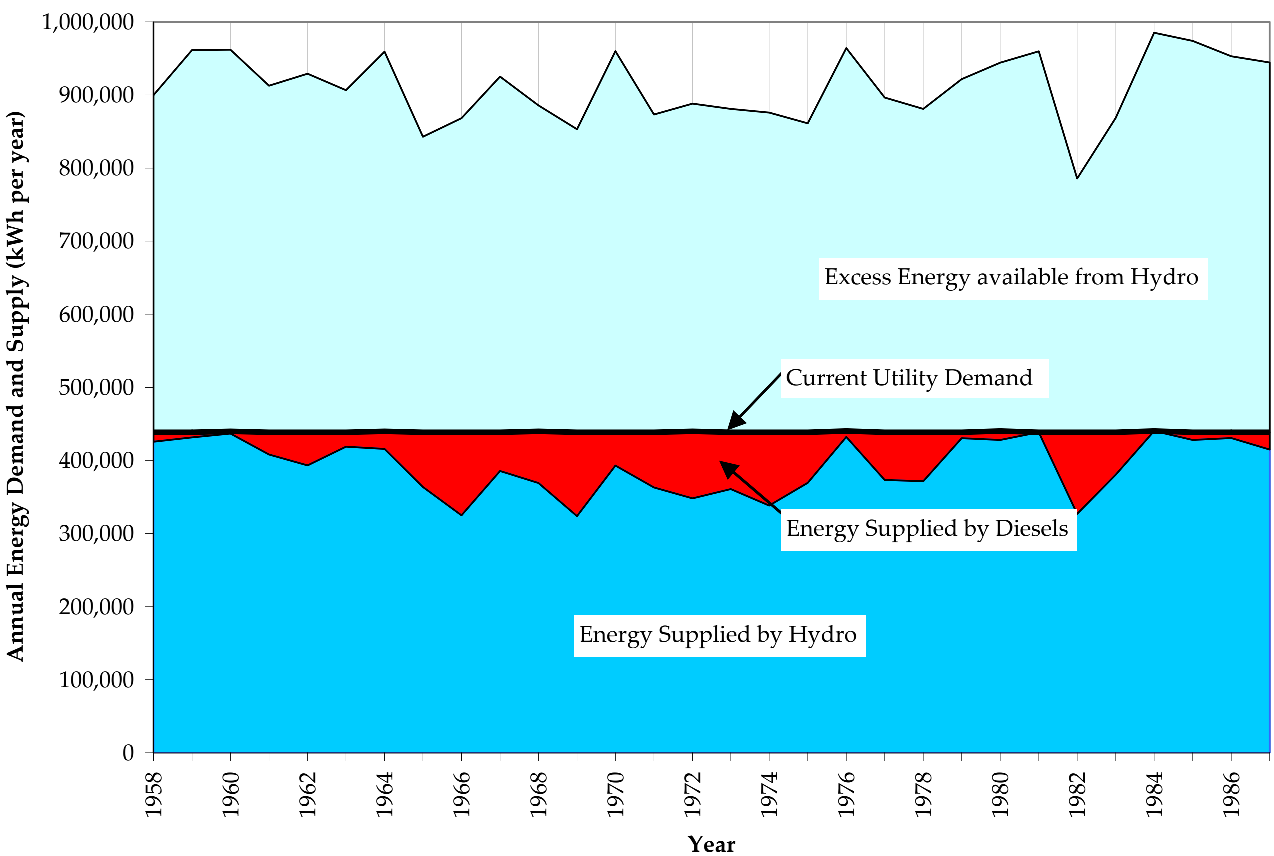
An analysis of the recommended project was performed using the 31 years of synthetic discharge data, a continuous year-round 10 cfs bypass for fish passage, and an hourly load model for TSEUD. The load model was developed from TSEUD's monthly peak demand data, monthly energy usage data, and annual energy usage data. Hourly demand was synthesized using a program developed by the National Renewable Energy Laboratory (NREL) based upon data for Alaska villages. [10] Load model and actual TSEUD system statistics are compared in Table 4-2. Simulated annual energy production is summarized in Figure 4-2 and Table 4-3.

Table 4-2: TSEUD Actual and Modeled System Electrical Demand Statistics

Parameter	Actual TSEUD Data	Load Model
Peak Load (kW)	120 [1]	120
Average Monthly Load (kW)	50	50
Total Annual Energy Demand (kWh)	440,000	438,500

TSEUD data is complied from utility records and PCE reports from 2002 – 2009.
Note 1: several peaks in the 120 – 180 kW range occurred in 2006. These are inconsistent with the record from 2002 – 2009, and are attributed to the system upgrades that occurred that year.

Figure 4-2: Annual Energy Demand, Diesel and Hydro Generation, and Hydro Surplus



10 *The Alaska Village Electric Load Calculator*, NREL/TP-500-36824, NREL, Golden Colorado, Sept. 2004.

Table 4-3: Annual Energy Demand, Diesel and Hydro Generation, and Hydro Surplus

Annual Energy	Minimum Hydro Years ('66, '69, '82)	**Average**	Maximum Hydro Years ('60, '81, '84)
System Demand (kWh)	-	**438,800**	-
Demand Met by Hydro (kWh)	323,700	**392,100**	438,800
(percent of demand by hydro)	74%	**89%**	100%
Demand Met by Diesels (kWh)	115,100	**46,700**	0
(percent of demand by diesels)	26%	**11%**	0%
Excess Hydro Energy Available (kWh)	347,200	**472,000**	545,000
(excess hydro as percent of total demand)	79%	**108%**	124%

On average, diesel generation would still be necessary to supply about 11% of TSEUD's annual energy demand. Diesel generation would typically be necessary in the late summer (July and August) and late winter / early spring (January to March) when flows are lowest. Figures 4-3 and 4-4 show daily demand and generation for 1982, a low water year, and 1970, an average water year.

Figure 4-3: Daily System Demand and Generation by Source for 1982 (Low Water Year)

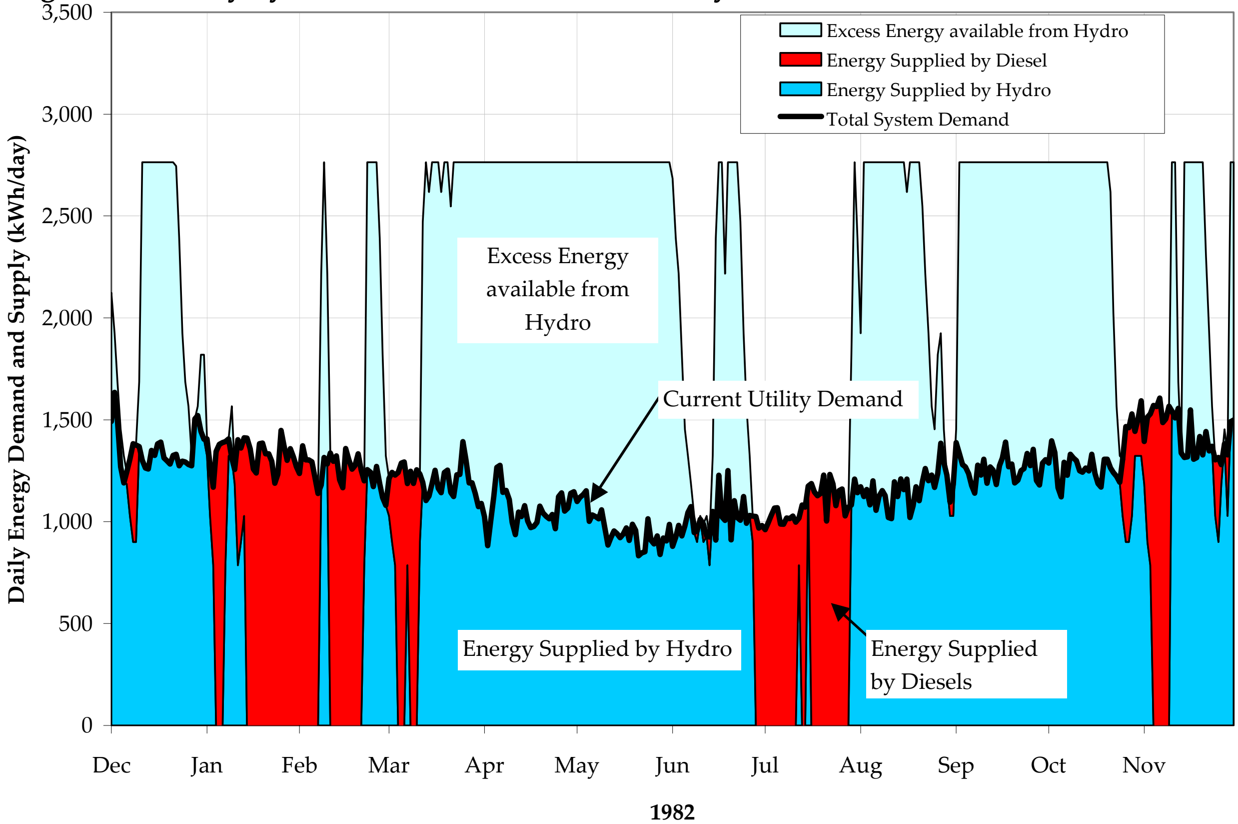
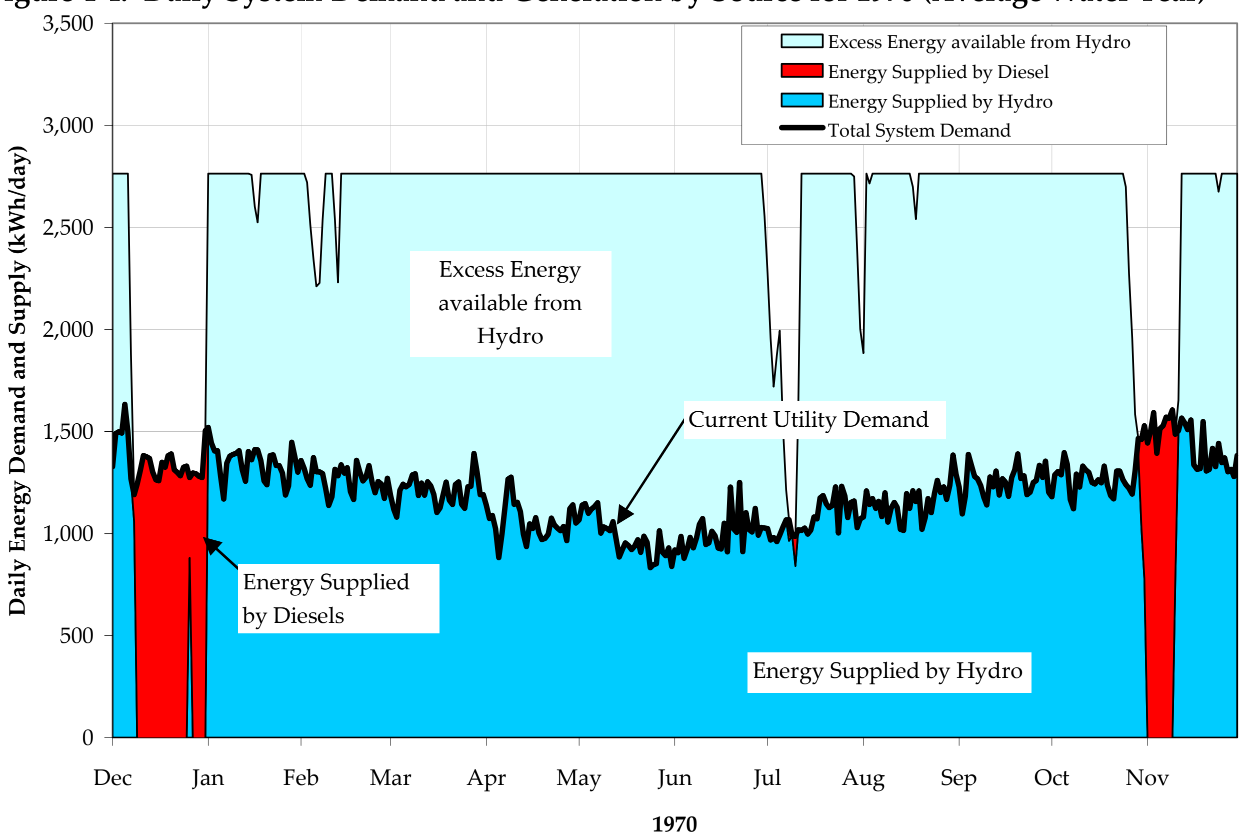
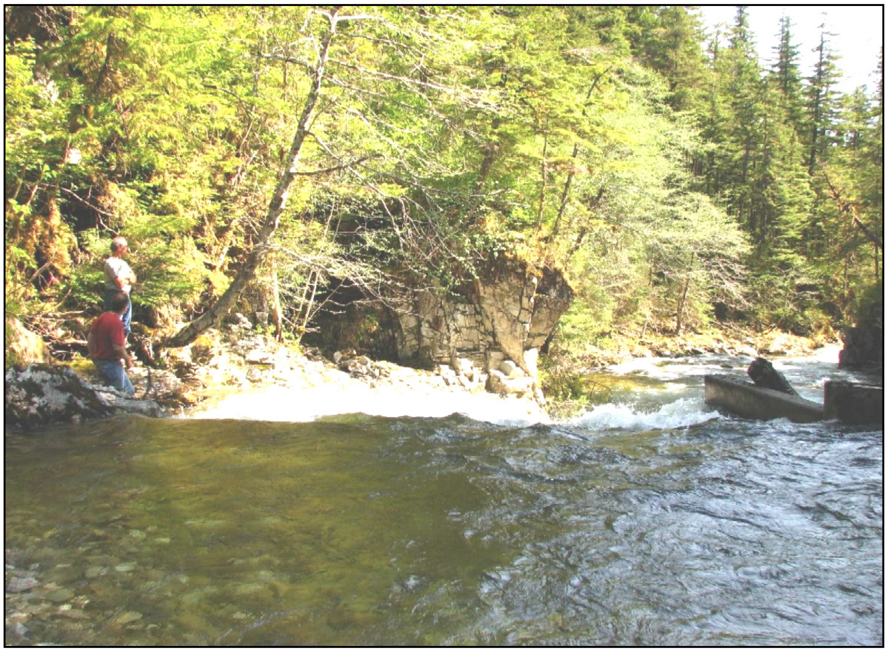


Figure 4-4: Daily System Demand and Generation by Source for 1970 (Average Water Year)



4.4 CONCEPTUAL SYSTEM DESIGN

4.4.1 Intake


Recommended intake location at the top of barrier 4, looking downstream. The headwall of the existing USFS fish ladder is visible at the far right.

The intake would be located at the top of barrier 4, adjacent to the existing head wall for the fish ladder. The intake structure would consist of a concrete or grouted steel frame set perpendicular to the flow of the water at the head of the falls. This frame would measure approximately 30 feet long by 3 feet wide, and it would be designed so the top dropped at about a 45-degree angle in the direction of flow. A series of metal screens would be set into the top of this frame. These screens would use the coanda effect to pull water from Indian River as it passed over the frame and screens.

The slot opening in the screens would be approximately 0.05 to 0.10 inch. This slot size would reject fish and most debris in the water. The frame would include gates to allow the area beneath the screens to be flushed out when necessary. These gates could be automated or manual. The orientation of the screens downstream and below the frame would help to protect them from damage from water-borne debris. The frame would be designed so the screens could be readily removed and replaced in manageable sections.

The hydro intake structure could include a number of features to aid in maintenance of both the intake and the adjacent fish ladder:

- Posts or piers to allow placement of a removable gangway to access the fish ladder.
- Sill height set to direct low flows into the fish ladder. Possibly slots to allow for installation of stop logs to direct low flows.
- Power and low bandwidth communications to aid in monitoring performance of the fish ladder.

4.4.2 Penstock

The penstock would be a 30-inch pipe surface mounted along the east bank of Indian River. Where possible, a narrow bench would be dug into the hillside and the penstock secured to on-grade timbers. In steeper or unstable areas, timber supports would be installed at 10- to 15-foot intervals and secured to bedrock via rock bolts. The penstock would be able to self-span across such supports. If longer spans are necessary, a timber frame and intermediate cradles would be used to support the penstock. The penstock design would need to accommodate thermal expansion of the pipe. Power and communications cables from the powerhouse to the intake would be installed adjacent to the penstock in conduit. Variations of this design approach, such as complete use of benching or timber supports, are possible.

Some blasting would likely be necessary immediately below the intake site to form a bench for the penstock. Additional blasting may be necessary in other areas along the route.

The penstock would likely be constructed of steel or high-density polyethylene (HDPE) pipe. Benefits of using steel would include the ability of the pipe to self support for much longer spans, and easier repair of the penstock in the event of major damage (such as a direct hit from a tree fall). Downsides of steel relative to HDPE include greater likelihood of damage from tree falls, increased construction difficultly, and decreased useful life. The material selection for the penstock will be determined in the design phase.

4.4.3 Powerhouse

The powerhouse would be approximately 24 feet by 20 feet, and would house the turbine, generator, controls, and switchgear. A 150-kVA transformer would be located adjacent to the powerhouse. The powerhouse foundation would be concrete or steel.

The turbine would be an Ossberger crossflow turbine. These turbines have fairly flat efficiency curves down to about 50% of their design flow. As available flow decreases from 50% to 25%, turbine efficiency decreases about 10%. Below approximately 25% of the design flow, these turbines cannot function. The turbine would be equipped with a draft tube to increase output. The draft tube is fitted below the turbine, and uses the head between the turbine and the tail water surface to pull a slight suction on the turbine, increasing its power generation.

The turbine would be coupled to a generator via a belt-drive speed increaser. These are preferred over gear boxes because they have similar power transfer efficiency, good life on the belts, and are much simpler to maintain and replace.

The generator would be a three-phase synchronous generator with a speed of 1200 or 1800 rpm. Estimated full-flow water-to-wire efficiency at the generator leads would be about 70%.

4.4.4 Power Line

The power line connecting the powerhouse to the TSEUD distribution system will be a three-phase 7.2 kV line. It will be overhead leaving the power house to cross Indian River. On the other side of the river, the power line will be installed in conduit and buried to protect it from falling trees and limbs.

An overhead line, either on poles or on tree cable, was considered. While a buried power line will have a higher initial cost, the buried line will be more reliable, because it will be less prone to damage from falling trees or limbs in ice and wind storms. The cost of outages and line maintenance over the life of the project is about the same as the additional cost of the buried line. The buried line is also used because it is expected to have greater reliability and superior aesthetics.

View looking southeast of forested terrain typical of the proposed power line routes between hydro powerhouse and Tenakee Springs. Tenakee Springs is located to the right of this view.

4.4.5 Site Access

Access trails for small vehicles will be built from the logging road to the powerhouse and intake sites and, where possible, along the penstock route. In the design phase, the need for these access trails will be scrutinized to determine if less-costly construction is possible with decreased use of trails and increased use of other methods such as helicopters.

4.4.6 Construction Methods

The use of force account labor methods is assumed to maintain better control over labor productivity and cost.

Labor housing is assumed to be provided by a temporary camp along the logging road. Housing in Tenakee may be logistically simpler and/or less costly.

All construction materials would be offloaded from barges at the log dump site. Materials would be staged at the construction sites either by land vehicles or by helicopter. Some items, such as the powerhouse structure, could possibly be prefabricated and delivered to the site by helicopter.

Penstock pipe would be shipped in 40-foot segments. If HDPE pipe is used, a fusion machine would need to be rented and shipped to the site to fuse the pipe into three approximately 500-foot long segments. These segments would then be carefully dragged and/or winched into their final locations in the canyon. Each segment would weigh about 20,000 pounds. Properly protected, this can be dragged by a D-4 or similar small tractor.

4.5 Conceptual Integration Design

The hydroelectric generator will be a 480-volt synchronous machine and transformer connected to the TSEUD 7.2 kV distribution system via a dedicated power line. A manual disconnect and fuse will be located in town at the point of interconnection. A separate dedicated controls wire will be installed between the hydro powerhouse and the diesel powerhouse to coordinate operations between the various generator sets.

Because this is a high-penetration renewable energy resource, the town’s diesels can be turned off for a significant amount of the time. This will help to extend the life of the diesel engines, reduce usage of consumables, and conserve fuel. The hydro project switchgear will be integrated with the diesel plant switchgear to optimize and automate operations. When the hydro project’s energy output is close to or less than the system’s load, the switchgear will start diesel genset(s) as necessary to parallel with or replace the hydro depending on water availability and system load.

5.0 ECONOMIC ANALYSIS

5.1 ESTIMATED PROJECT INSTALLED COST

The estimated installed cost for the recommended Indian River hydro project is $2,590,000. This is presented in Table 5-1. A more detailed estimate is presented in Appendix B.

Table 5-1: Estimated Installed Cost for Indian River Hydroelectric Project

Item	Estimate
Pre-Construction Activities	**$208,000**
Construction (labor, equipment, materials)	
Power Line	$342,000
Powerhouse / Generation Equipment	$396,000
Project Access	$145,000
Penstock Sitework / Access	$431,000
Penstock Construction	$106,000
Intake Structure	$52,000
Construction Equipment	$142,000
Shipping	$137,000
Direct Construction Cost	**$1,752,000**
Project Administration / Management	$102,000
Construction Engineering / Inspections / Commissioning	$102,000
Contingency (20%)	$350,000
Financing (3%)	$75,000
Installed Cost	**$2,590,000**

5.2 ANNUAL PROJECT COSTS

Annual project costs are summarized in Table 5-2 and discussed in the following sections.

Table 5-2: Annual Project Costs for Indian River Hydroelectric Project

Cost Item	Annualized Cost Hydroelectric Project
Hydro Operations & Maintenance	$15,200
Diesel Operations and Maintenance	-$7,700
Hydro Repair & Replacement	$10,800
State Lease Royalties	$3,900
Annual Project Operations Costs	**$22,200**
Debt Service (for 100% financed project)	$132,200
Total Annual Project Costs	**$154,400**

5.2.1 Operation and Maintenance

Total non-fuel O&M costs for TSEUD have averaged about $51,000 annually over the past several years.[11] This annual expense includes activities such as meter reading, customer service, managing customer accounts, etc. These costs will not change if the means of energy generation changes from diesel to hydroelectric or a combination of both.

This annual expense also includes the costs of lube oils, filters, and other consumables for the diesel generators, maintenance labor, and similar costs that are directly tied to the running time or energy generation of the diesel power plant. Some of these costs will be avoided with a hydroelectric project.

Because the diesels would be run less often and would be run at a lighter loading with the hydroelectric project in service, they would use fewer consumables and would require less-frequent overhauls. These are assumed to be worth 15 percent of total annual non-fuel expenses, or $8,000 annually.

The hydroelectric project will have operation and maintenance costs. Based on experience with similar projects, annual O&M costs are estimated to be $15,000 annually. This includes additional labor costs for monitoring and maintaining the hydro as well as direct expenses for parts and consumables.

5.2.2 Repair and Replacement

Low frequency natural events such as wind storms and floods may periodically damage portions of the hydroelectric project. Damage might occur to the intake (flood debris damaging the screens), power line (tree roots ripping up conduit), penstock (flood induced erosion, falling trees and limbs), and powerhouse (wind storms or falling trees and limbs). The estimated annual cost to repair such damage is listed in Table 5-2.

Most of the hydroelectric project systems and components have a very long useful life. The intake, penstock, powerhouse, switchgear, turbine/generator, and power line all have useful lives of at least 30 years. Some portions of the project will require periodic repair or replacement. Portions of the penstock trail that are constructed with timbers may start to require replacement at 15 years. Similarly, the intake screens are assumed to have a 15-year useful life. Some minor electric components, such as the hydraulic pumps, control sensors, and similar devices, are assumed to have a useful life of five years.

[11] See Table 2-4.

5.2.3 Property

The recommended hydroelectric project is located on state land. On recent renewable energy leases, the Alaska Department of Natural Resources (ADNR) has required annual lease payments of either $1,000 per acre or 2.5% of gross revenue to the leaseholder. These lease fees have been levied against publicly owned utilities such as Kodiak Electric Association, Inc. (organized as a rural electric cooperative) so it is probable that they would be levied against TSEUD. [12]

Because of the modest size of a lease for the powerhouse and intake sites (about an acre combined), it is assumed that ADNR would levy the 2.5% gross revenue royalty against the TSEUD. This is consistent with ADNR's management directive to encourage development of state lands for maximum benefit of the state's citizens. This royalty payment is estimated to be approximately $4,000 per year.

5.2.4 Taxes

Because TSEUD is a department of a local government, it will not need to pay any taxes.

5.2.5 Insurance

It is assumed that the City of Tenakee's and TSEUD's existing insurance coverages would cover the hydroelectric project. No annual cost is allocated for insurance.

5.2.6 Financing

The costs of financing will depend on the type of financing used for the project. Financing options vary from government grants or loans to commercial financing options such as bonding.

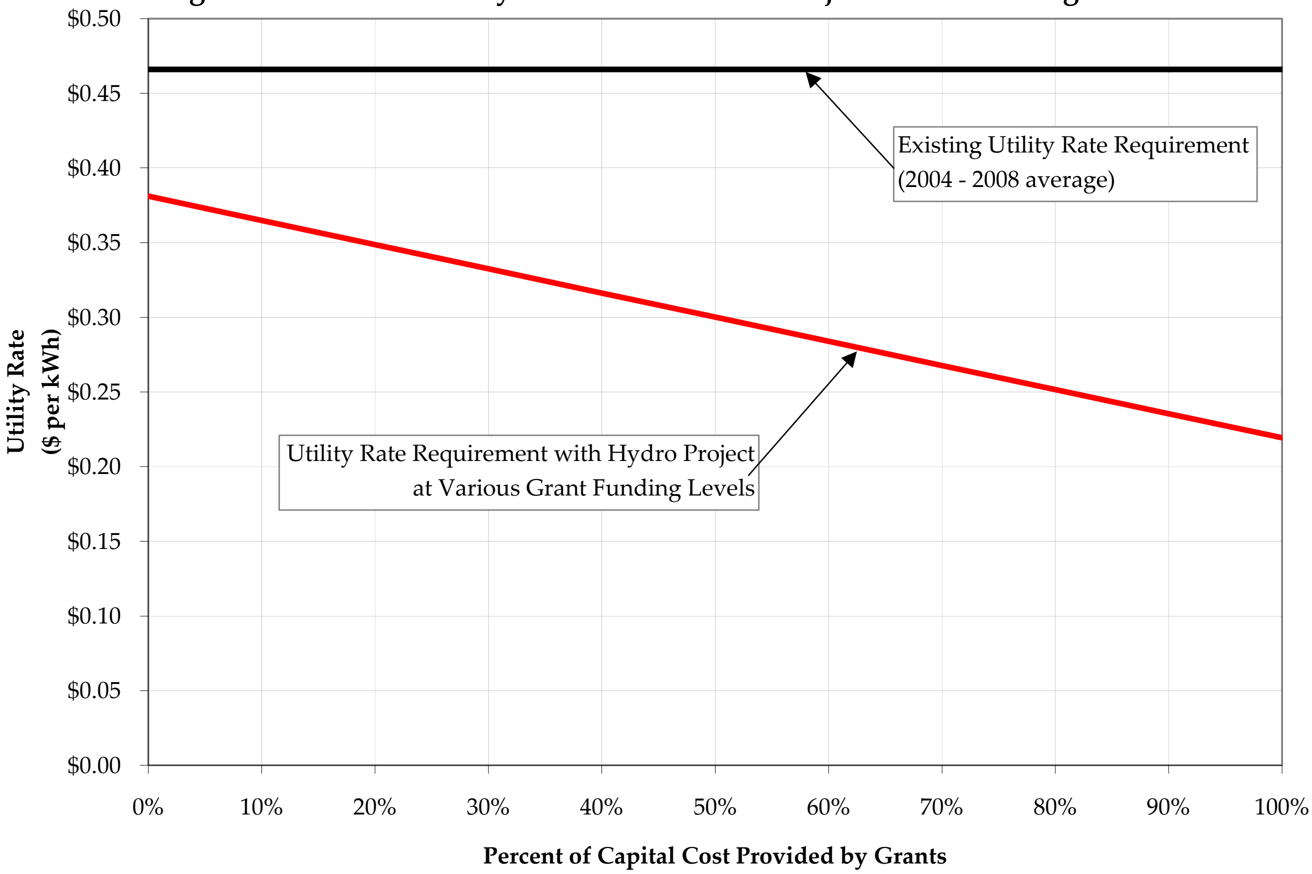
Commercial finance for the project is assumed to consist of a 30-year bond at a nominal interest rate of 6%. Adjusted for inflation (assumed at 3% average over 30 years), this is a real interest rate of approximately 3%. In addition, the cost of preparing and issuing the bond adds about 3% to the cost of the project (for items such as loan guarantee fees, origination fees, etc). This cost is included in considering the cost of financing options for the project. With these assumptions, the annual costs of debt servicing for a fully-bonded project is $132,140.

There are costs associated with government grants, but they are generally modest and vary with the specific type of grant and granting agency used.

[12] See ADNR's preliminary decision for the lease of state land to Kodiak Electric Association, Inc. for the Pillar Mountain Wind Farm, ADL 229859, issued February 2009.

Figure 5-1 presents the utility rates ($/kWh) needed to finance the project at various grant levels. Lowest rates occur with 100 percent government grants (electric rates need only cover annual operating costs), and highest rates occur with 100 percent commercial financing (electric rates need to cover annual operating costs and debt service). Figure 5-1 reflects the full utility costs, and has not been adjusted for PCE subsidies.

Figure 5-1: Electric Utility Rates for Different Project Grant Funding Levels



5.3 PROJECT REVENUES AND SAVINGS

Table 5-3 presents annual project revenues and savings achieved with the recommended hydro project. These items are discussed in the following sections.

Table 5-3: Estimated Annual Project Revenues and Savings

Revenue Item	Estimated Annual Value
Displaced Power Plant Fuel Costs	
Diesel kWh Displaced by Hydro Project	392,200 kWh
Amount of Fuel Displaced by Hydro Project	31,400 gallons
Fuel Costs Displaced by Hydro Project (at $3.50 per gallon)	**$109,800**
Fuel Displaced by Excess Energy	
Gross Excess Energy Available from Hydro Project	446,800 kWh
Net Excess Hydro Energy Dispatched and Metered [1]	347,000 kWh
Amount of Fuel Displaced by Excess Hydro Energy [2]	13,000 gallons
Fuel Costs Displaced by Excess Hydro Energy (at $3.50 per gallon)	**$45,600**
Revenue from Sale of Environmental Attributes on Voluntary Market	
Annual kWh of energy from project	839,000 kWh
Percentage of available environmental attributes sold	100%
Sales Price for environmental attributes	$0.01 per kWh
Revenue from Sale of Environmental Attributes on Voluntary Market	**$8,400**
TOTAL ANNUAL REVENUES AND SAVINGS	**$163,800**

Note 1: Assumes 90% utilization of excess energy, and 13.6% losses over TSEUD system.
Note 2: Assumes excess energy displaces oil used by space and water heating systems with an average efficiency of 65%.

5.3.1 Fuel Displacement

Based on modeling results, the recommended hydro project will displace an average of 392,125 kWh annually that are currently generated with diesel fuel. Using TSEUD's existing generation efficiency of 12.5 kWh/gallon, this equals 31,370 gallons of displaced diesel annually. At a price of $3.50 per gallon, this represents a direct annual savings of $109,800 to TSEUD.

5.3.2 Excess Energy

In addition to the diesel electric generation that the hydro displaces, it also generates an annual average of 447,000 kWh of excess energy that is available for the community to use. For economic analysis purposes, 10% of this gross excess energy is assumed to be consumed by the hydro load governor system, and 90% is assumed to be made available to discretionary system loads such as space heating and water heating uses. Of this 90%, 13.6% is assumed to be consumed by losses on TSEUD's distribution system. The balance (77.8% of gross excess energy generation) is metered to TSEUD's accounts. All of this excess energy is assumed to completely displace heating fuel being consumed in boilers, furnaces, and hot water makers with an average efficiency of 65%. With these assumptions, this excess energy displaces an average of 13,035 gallons of heating fuel annually. At $3.50 per gallon, this is worth $45,623 annually.

5.3.3 Environmental Attributes

As a small, low-impact, run-of-river hydroelectric project, this hydro project would have the ability to market its environmental attributes nation-wide. The market for environmental attributes is still developing, and as a result is subject to considerable uncertainty. There is federal and state legislation pending that could influence this market, transforming it from the existing patchwork of state compliance markets and national and regional voluntary markets into a more uniform and regulated national market. A reasonable range for the value of the environmental attributes from this project is $0.005 to 0.020 per kWh on the voluntary market, equal to $4,200 to $16,800 annually.

Tenakee Springs has the potential to market its picturesque Alaska setting and the fisheries enhancements on Indian River to command a premium for it environmental attributes. For the economic analysis, they are valued at $0.010 per kWh, which equates to $8,400 of revenue annually.

5.4 INDIRECT AND NON-MONETARY BENEFITS

The recommended hydroelectric project offers significant indirect and non-monetary benefits in addition to direct economic benefits. These other benefits include:

- Reduced air pollution (NOx, SOx, particulates, and hydrocarbons) due to decreased operation of the diesel power plant.
- Reduced noise when the diesel plant is turned off. Because the diesel power plant is somewhat removed from the rest of the community, this is a minor benefit.
- Reduced risk of oil spills due to decreased throughput and handling of fuel.
- More stable energy prices. With the hydro, TSEUD’s electricity rates will be largely insulated from increasingly volatile world oil prices.
- Secondary benefits arising from the availability of plentiful hydropower with a stable price. This will increase the affordability of living and doing business in Tenakee Springs, and will increase the long-term viability of the community. Secondary benefits could include an increase in the population of school-age children, ensuring that school enrollment exceeds district and state thresholds for state funding year-to-year.
- Economic multipliers due to the fact that a greater percentage of the utility's revenues will be retained in the local community for labor instead of paying external entities such as fuel suppliers.
- Local training and experience with small hydroelectric projects. To the extent that locals choose to be involved in construction, maintenance, and operation of the hydro, they

will learn a unique set of skills. These skills will become increasingly useful as Alaska in general and southeast in particular continues to develop local hydropower resources.

5.5 LIFE-CYCLE COST AND BENEFIT–COST RATIO

Table 5-4 presents life cycle costs and benefit to cost ratio for the recommended project.

Table 5-4: Life Cycle Costs and Benefit-Cost Ratio

Item	Estimate
PROJECT COSTS	
Installed Cost of Project	**$2,590,000**
Annual Operations Costs (50 years)	$22,200
Debt Servicing (100% financed project, 30 years)	$132,200
Project salvage value at year 50	$0
Total Annual Costs	**$154,400**
PRESENT WORTH OF PROJECT COSTS	**$3,161,000**
PROJECT REVENUES / SAVINGS	
Avoided Utility Fuel Costs (50 years)	$109,800
Avoided Fuel Costs from Use of Excess Energy (50 years)	$45,600
Revenue from Environmental Attributes (50 years)	$8,400
Total Annual Savings / Revenues	**$163,800**
PRESENT WORTH OF PROJECT REVENUES / SAVINGS	**$4,215,000**
BENEFIT TO COST RATIO	**1.33**

Notes:
A real discount rate of 3% is used for time value of money for all calculations.

5.6 Sensitivity Analysis

Inputs to the economic analysis were varied to evaluate the effect they have on the project's economic feasibility. Inputs evaluated are summarized in Table 5-5. Results are discussed in the following sections.

Table 5-5: Sensitivity Analysis of Key Project Economic Parameters

Parameter	Base Value	Range Considered	Range of Resulting Benefit-Cost Ratio	Value for Benefit-Cost Ratio of 1.00
Capital Cost	$2,590,000	+/- 25%	1.11 to 1.68	$3,650,000 (41% over cost estimate)
Annual Operations Costs	$22,200/yr	+/- 50%	1.22 to 1.47	$63,000/yr (284% over cost estimate)
Real Financing Rate [1]	3%	0 to 7%	0.90 to 1.86	6%
Cost of Avoided Fuel	$3.50 per gallon	$1.50 to $5.50	0.62 to 2.02	$2.55/gal
Percent Utilization of Excess Energy	90%	0% to 100%	0.97 to 1.37	6%
Environmental Attributes Sales Price	$0.01 per kWh	$0.00 to $0.03	1.27 to 1.47	N/A

Note 1: The real financing rate is the nominal rate less the rate of inflation. So if the project is financed at 6%, and inflation over the life of the bonds averages 3%, then the real interest rate on the debt is 3%.

The project is most sensitive to two parameters:

- Avoided cost of fuel.
- Financing cost.

The project is sensitive to the price of fuel used for diesel generation and space heating. Under the 100 percent debt-financed base scenario for the project, the benefit-cost ratio is 1.00 at a fuel price in Tenakee Springs of $2.55 per gallon. TSEUD paid less than this price as recently as 2004.

While the long-term fuel cost is considered unlikely to be below $2.55 per gallon delivered in Tenakee Springs, temporary decreases below this price are possible.

A 100 percent debt-financed project is not viable if real interest rates for project financing are greater than 6 percent. Using a long-term inflation forecast of 3 percent, this equates to a 9 percent nominal interest rate. Government loan programs such as the State of Alaska's Power Project Fund offer rates well under 9 percent. Government grants would also help to lower this threshold for the city.

6.0 PERMITS

Permits required for the recommended project are summarized in Table 6-1. Permit requirements and agency involvement are discussed in greater detail in the following sections.

Table 6-1: Major Permits Required for the Recommended Hydro Project

Agency / Entity	Permit / Finding / Action	Comments
Federal Energy Regulatory Commission	Finding of Non-Jurisdiction	-
U.S. Army Corps of Engineers	Wetlands Permit, NWP 17	-
U.S. EPA	Stormwater Pollution Prevention Plan	-
ADNR Coastal Zone Program	Coastal Management Consistency Review	Starts after COE process
ADNR Property Rights	Transfer / Lease / Easement Authorizations	-
ADNR Water Rights	Water Use Permit / Water Rights	Requires 'possessory interest' in property before issuance.
ADFG	Fish Habitat Permit	Starts after Coastal Review

6.1 FEDERAL PERMITS

6.1.1 FERC

A hydropower development generally falls under the jurisdiction of the Federal Energy Regulatory Commission (FERC) if it meets one of three criteria:

- Occupies in whole or part federal lands.
- Is located on navigable waters.
- Is connected to an interstate electrical grid.

If a project is under FERC jurisdiction, it must obtain a FERC license or exemption from FERC licensing. Normally, all of the state and federal permits required for a FERC hydroelectric project are obtained through the formal FERC licensing process. This process typically takes three or more years to complete, and requires extensive consultations with resource agencies, site investigations, and analysis.

The recommended project would not occupy federal lands or connect to an interstate power grid. Indian River is not believed to meet navigability criteria, therefore this project is non-jurisdictional.

FERC jurisdiction is determined by filing a declaration of intention with FERC. If FERC concurs that the project is non-jurisdictional and this finding is not contested, then FERC licensing is not required for this project.

6.1.1.1 FERC Licensing

If FERC determines that the Indian River is navigable, then the City must proceed with the FERC process to develop this project. In this event, it is recommended that the City pursue an exemption from FERC licensing.

6.1.1.2 Exemptions from FERC Licensing

FERC regulations provide for eligible projects under 5 MW in capacity to be exempted from the licensing process. The 5 MW exemption allows a project that utilizes a 'natural water feature' to go through an abbreviated process that results in a permanent exemption from FERC licensing. To use this exemption process:

- The project must utilize a 'natural water feature'.
- The project must own all lands and facilities other than federal lands.

6.1.2 U.S. Forest Service

No USFS permits are required for the proposed project. However, the USFS has substantial investments in fish-passage structures on Indian River. Project design should be coordinated with the USFS to insure that the functionality and integrity of these structures is preserved or enhanced.

The USFS holds a lease with the state of Alaska for their fish ladder constructed at barrier 4 in 1998. The intake for the recommended project would be located adjacent to and possibly integrated with the top of this fish ladder structure. Accordingly, the intake structure for the hydro project will probably lie within the USFS' fish ladder lease site. [13]

6.1.3 U.S. Army Corps of Engineers Permits

The project intake and tailrace will be located within wetlands, therefore a wetlands permit from the COE will be required. Other project features such as the power line may also be located partially in wetlands. The project is likely eligible for a Nationwide Permit #17 for small hydroelectric development.

[13] ADNR was contacted to obtain an as-built of the fish ladder lease. They do not have as as-built in their records. (September 15, 2009).

6.1.4 U.S. Environmental Protection Agency

A stormwater pollution prevention plan (SWPPP) will be required for project construction.

6.1.5 Federal Aviation Administration

The project is not located within five miles of any airport. The project will not have any features likely to present a hazard to aviation. No FAA approvals are necessary.

6.2 STATE OF ALASKA PERMITS

6.2.1 Department of Natural Resources Permits

6.2.1.1 Coastal Zone Consistency Review

The recommended project is located within the State's Coastal Zone. Coastal zone consistency review will be required. This process is initiated by completing a coastal project questionnaire and submitting it to ADNR's Division of Coastal and Ocean Management (DCOM).

6.2.1.2 Land Authorizations

The project would occupy state land. Land easements or leases, or land purchase / transfer, will be necessary to construct the project.

6.2.1.3 Tidelands Permits

Not applicable.

6.2.1.4 Material Sale Agreement

An existing quarry is located on state land about one mile down the logging road from the intake / powerhouse access points. ADNR Mineral Order (MO) 1045 closed lands within sections 15, 21, 22, and 23 to mining in 2006. MO 1045 included this quarry. It is unknown if the state would reopen this quarry for material for the project. Alternate material sources could be beach run or imported aggregates. Beach run aggregates would need to be washed before used for concrete work to flush out chlorides. Local material sources would require a material sale agreement from ADNR.

6.2.1.5 Water Use Permit / Water Rights

The project would need to obtain water rights from the ADNR.

6.2.2 Department of Fish and Game Permits

6.2.2.1 Fish Habitat Permit

The project would need to obtain a fish habitat permit from the ADFG.

6.2.3 Department of Transportation Permits

Not applicable.

6.2.4 Department of Environmental Conservation Permits

6.2.4.1 DEC Wastewater or Potable Water Permits

Not applicable.

6.2.4.2 Solid Waste Disposal Permit

It may be desirable to dispose of bulky inert construction wastes from the project in an on-site monofill. This would require an ADEC monofill permit and approval of the land owner, ADNR.

6.2.4.3 Air Quality Permit& Bulk Fuel Permit

Not applicable.

6.3 LOCAL PERMITS

The project is not located within the limits of a borough. The project is located with the city limits of Tenakee Springs. No local permits or approvals are required.

7.0 ENVIRONMENTAL CONSIDERATIONS

7.1 THREATENED AND ENDANGERED SPECIES

The project is not located within any designated critical habitat areas for threatened or endangered species.

7.2 FISHERIES AND WILDLIFE

Development of a hydroelectric project at Indian River is not likely to have any significant impact on wildlife in the area.

View of the top of the existing USFS fish ladder at barrier 4.

Development of a hydroelectric project at Indian River has the potential to affect fish habitat and fish passage on Indian River. The reach of Indian River that would be dewatered by the project is not good fish habitat. It is, however, an important fish passage to good habitat areas upstream. The USFS has built a substantial fish ladder at barrier 4 and step pools at barrier 5 to make it easier for salmon to reach these upstream spawning and rearing areas.

USFS has determined that minimum flows necessary for the fish ladder at barrier 4 is 10 cfs. [14] The project would therefore need to maintain minimum flows at this ladder during critical fish migration periods.

The project has the opportunity to improve function and monitoring capabilities at the fish ladder. These opportunities include:

- Proper design of the intake structure can increase flow into the fish ladder at extreme low flows, improving fish passage around barrier 4.
- The intake structure can incorporate a creek crossing, improving access to the fish ladder for maintenance and monitoring.

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[14] If the hydro project intake is properly designed, a lesser minimum flow for the fish ladder may be possible. See discussion of this issue at Section 3.2.3).

- The project will include communications to the intake site for head level control. Communications bandwidth can be provided at modest additional cost for real-time monitoring of data such as flow or fish counts at the fish ladder.
- If the project extends power to the intake site, it can be made available for improved fish monitoring at the fish ladder.

7.3 WATER AND AIR QUALITY

By reducing the amount of diesel fuel burned in Tenakee Springs for electricity generation, this project will tend to improve air quality by reducing local NO_X, SO_X, hydrocarbon, and particulate emissions. If excess energy available from the project is dispatched to space or water heating purposes, additional combustion of heating fuel and/or wood is possible, further reducing local airborne emissions.

The project is a run-of-river project and does not store or detain water. As a result, the project does not significantly change the physical or chemical properties of the water.

7.4 WETLAND AND PROTECTED AREAS

The project intake and tailrace structures will be located in wetlands (Indian River). In addition, the penstock, project access trails, and power line to Tenakee Springs may cross wetlands and involve some fill of wetlands.

These impacts are expected to be minimal and should not significantly affect the natural environment.

7.5 ARCHAEOLOGICAL AND HISTORICAL RESOURCES

COE archeologists spent three man-days investigating the project area in the early 1980s investigating the presence of archeological and historical resources. No new significant resources were identified. [15] Two known cemeteries in the general vicinity of the project were identified and determined to not be impacted by the project.

7.6 TELECOMMUNICATIONS AND AVIATION

None.

[15] Appendix B – Tenakee Springs Cultural Resources Report. *Small Hydropower and Related Purposes Letter Report*, COE, 1984.

7.7 VISUAL AND AESTHETIC RESOURCES

Due to the heavy old-growth forest cover in the project vicinity, the project would not be prominently visible from any vantage point on land, at sea, or from the air. The project would be visible principally on the ground standing on or near the project works. The construction materials and methods proposed are considered to be consistent with and aesthetically complementary to the natural setting of the project.

7.8 MITIGATION MEASURES

No mitigation measures are necessary or recommended.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Based upon the analyses presented in this report, a hydroelectric project between the top of barrier 4 and the bottom of barrier 2 is technically and economically feasible at Indian River. The recommended hydro project is economically superior to continued diesel generation under all likely scenarios.

The project has a benefit-cost ratio of 1.33 under the base economic assumptions. Benefit-cost is most sensitive to fuel costs (BCR of 1.00 at $2.55/gallon) and project financing interest rates (BCR of 1.00 at real 6%, nominal 9%). Government grants or low-interest loans can help to reduce the community's exposure to these factors and move forward with the project.

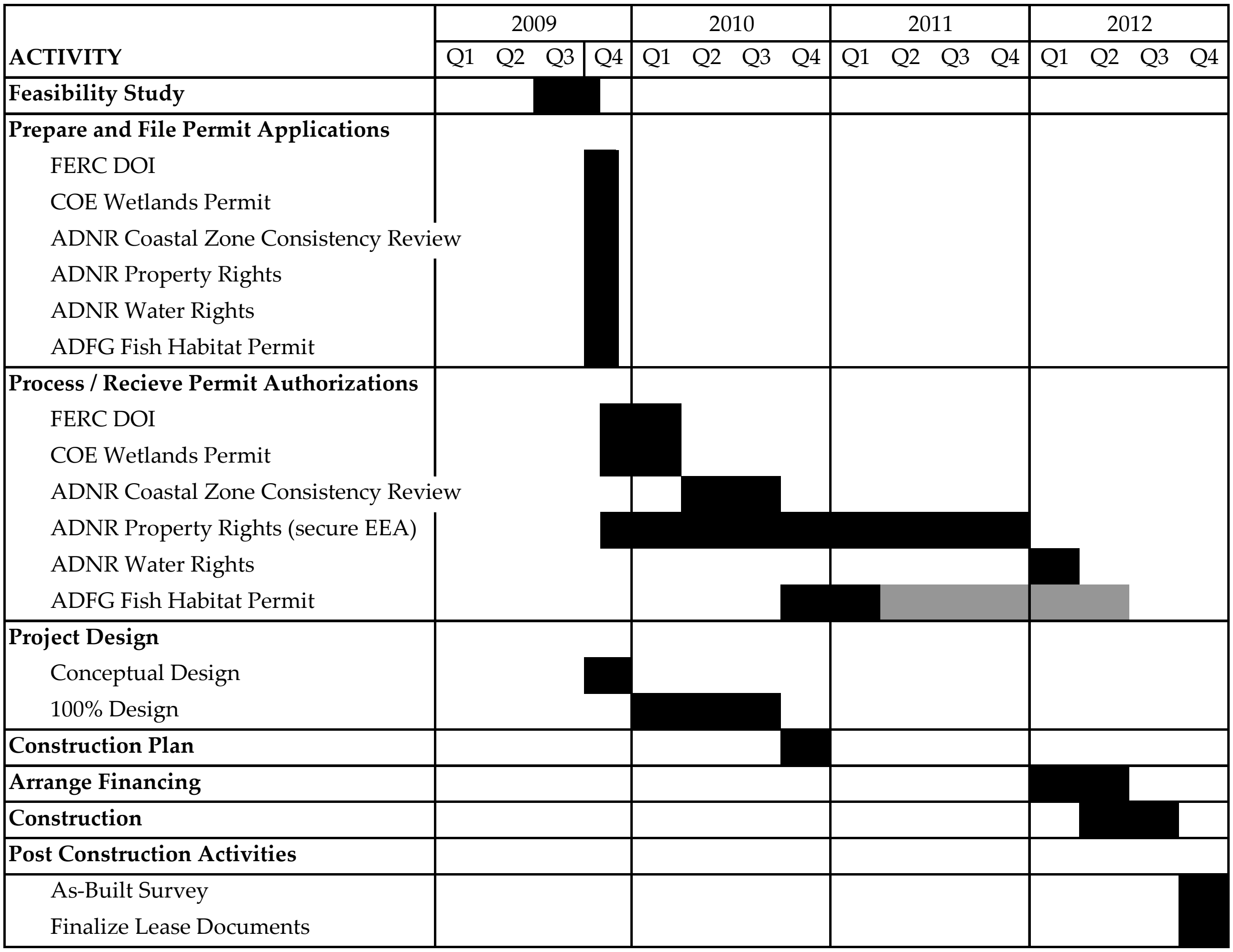
8.1 DEVELOPMENT PLAN & SCHEDULE

The next major steps to advance a hydro project on Indian River are:

1. Prepare and submit permit applications for the project.
2. Complete designs for the project.
3. Obtain all permits required for the project.
4. Secure construction funding.
5. Construction.

The longest potential lead times are securing the leases on state land. Depending on their backlog and staffing levels, it takes ADNR up to three years to process a lease application. It is recommended that the preparation and submittal of lease applications occur as soon as possible to start this process. With the exception of the ADNR lease, it is expected that all permits for the project could be issued in time for construction in 2011. The ADNR land lease could delay project construction to 2012 or possibly 2013.

Figure 8-1: Project Development Schedule



APPENDIX A – COST ESTIMATES OF ALTERNATIVES

APPENDIX A – COST ESTIMATES OF PROJECT ALTERNATIVES

Cost estimates were developed for the recommended project and alternative project configurations. Tables A-1 through A-4 present economic data for all of the project configurations considered in this study.

Table A-1: Estimated Installed Cost of Project Alternatives

Item	4 to 2 180 kW	**4 to 2 120 kW**	4 to 2 60 kW	4 to 1 120 kW	5 to 3 120 kW	5 to 2 120 kW	5 to 1 120 kW
Pre-Construction Activities	**$208,000**	**$208,000**	**$198,000**	**$223,000**	**$268,000**	**$276,000**	**$288,000**
Construction							
Power Line	$350,000	$342,000	$339,000	$461,000	$342,000	$342,000	$378,000
Powerhouse	$576,000	$396,000	$259,000	$416,000	$416,000	$384,000	$394,000
Project Access	$145,000	$145,000	$145,000	$145,000	$84,000	$128,000	$128,000
Penstock Sitework	$485,000	$431,000	$419,000	$785,000	$721,000	$866,000	$675,000
Penstock Construction	$138,000	$106,000	$94,000	$183,000	$161,000	$171,000	$211,000
Intake Structure	$73,000	$52,000	$38,000	$72,000	$53,000	$50,000	$48,000
Construction Equipment	$144,000	$142,000	$83,000	$122,000	$89,000	$89,000	$105,000
Shipping	$171,000	$137,000	$111,000	$180,000	$197,000	$214,000	$257,000
Direct Construction Cost	**$2,082,000**	**$1,752,000**	**$1,490,000**	**$2,364,000**	**$2,062,000**	**$2,243,000**	**$2,195,000**
Project Administration	$115,000	$102,000	$93,000	$142,000	$134,000	$146,000	$136,000
Construction Engineering	$115,000	$102,000	$93,000	$142,000	$134,000	$146,000	$136,000
Contingency (20%)	$416,000	$350,000	$298,000	$473,000	$412,000	$449,000	$439,000
Financing (3%)	$88,000	$75,000	$65,000	$100,000	$90,000	$98,000	$96,000
Installed Cost	**$2,936,000**	**$2,590,000**	**$2,171,000**	**$3,344,000**	**$3,010,000**	**$3,260,000**	**$3,194,000**

Table A-2: Annual Project Costs for Project Alternatives

Cost Item	4 to 2 180 kW	**4 to 2 120 kW**	4 to 2 60 kW	4 to 1 120 kW	5 to 3 120 kW	5 to 2 120 kW	5 to 1 120 kW
Hydro Operations & Maintenance	$15,200	$15,200	$12,700	$17,000	$16,700	$18,100	$20,000
Diesel Operations and Maintenance	-$7,400	-$7,700	-$7,800	-$7,900	-$7,700	-$7,900	-$8,000
Hydro Repair & Replacement	$11,000	$10,800	$10,600	$12,800	$12,500	$14,100	$16,300
State Lease Royalties	$4,300	$3,900	$3,000	$4,000	$3,900	$4,100	$4,200
Annual Project Operations Costs	**$23,000**	**$22,200**	**$18,000**	**$26,000**	**$26,000**	**$28,000**	**$33,000**
Debt Service (for 100% financed project)	$149,800	$132,100	$110,800	$170,600	$153,600	$166,300	$162,900
Total Annual Project Costs	**$172,800**	**$154,400**	**$128,800**	**$196,600**	**$179,600**	**$194,300**	**$195,900**

Table A-3: Estimated Annual Revenues and Savings for Project Alternatives

Revenue Item	4 to 2 180 kW	**4 to 2 120 kW**	4 to 2 60 kW	4 to 1 120 kW	5 to 3 120 kW	5 to 2 120 kW	5 to 1 120 kW
SAVINGS FROM DISPLACED POWER PLANT FUEL							
Diesel kWh Displaced by Hydro Project (kWh)	378,000	392,200	399,000	403,000	395,000	407,000	412,000
Amount of Fuel Displaced by Hydro Project (gallons)	30,000	31,400	32,000	32,000	32,000	33,000	33,000
Fuel Costs Displaced by Hydro Project (at $3.50 per gallon)	**$106,000**	**$109,800**	**$112,000**	**$113,000**	**$111,000**	**$114,000**	**$115,000**
SAVINGS FROM FUEL DISPLACED BY EXCESS HYDRO ENERGY							
Gross Excess Energy Available from Hydro Project (kWh)	791,000	446,800	72,000	482,000	454,000	494,000	512,000
Net Excess Hydro Energy Dispatched and Metered [1] (kWh)	478,000 [3]	347,000	56,000	375,000	353,000	384,000	398,000
Amount of Fuel Displaced by Excess Hydro Energy [2] (gal.)	17,900	13,000	2,000	14,000	13,000	14,000	15,000
Fuel Costs Displaced by Excess Hydro Energy (at $3.50 per gallon)	**$63,000**	**$45,600**	**$7,000**	**$49,000**	**$46,000**	**$50,000**	**$52,000**
REVENUE FROM SALE OF ENVIRONMENTAL ATTRIBUTES							
Annual kWh of energy from project	1,169,000	839,000	471,000	885,000	848,000	900,000	924,000
Revenue from Sale of Environmental Attributes on Voluntary Market	**$11,700**	**$8,400**	**$4,700**	**$8,900**	**$8,500**	**$9,000**	**$9,200**
TOTAL ANNUAL REVENUES AND SAVINGS	**$180,700**	**$163,800**	**$124,000**	**$171,000**	**$165,000**	**$173,000**	**$177,000**

Note 1: Assumes 90% utilization of excess energy, and 13.6% losses over TSEUD system.
Note 2: Assumes excess energy displaces oil used by space/water heating systems with an average efficiency of 65%.
Note 3: Assumes Tenakee Springs can only absorb 70% of excess energy from larger project vs. 90% for others.

Table A-4: Life Cycle Costs and Benefit-Cost Ratios for Project Alternatives

Item	4 to 2 180 kW	**4 to 2 120 kW**	4 to 2 60 kW	4 to 1 120 kW	5 to 3 120 kW	5 to 2 120 kW	5 to 1 120 kW
PROJECT COSTS							
Installed Cost of Project	**$2,936,000**	**$2,590,000**	**$2,171,000**	**$3,344,000**	**$3,010,000**	**$3,260,000**	**$3,194,000**
Annual Operations Costs (50 years)	**$23,000**	**$22,200**	**$18,000**	**$26,000**	**$26,000**	**$28,000**	**$33,000**
Debt Servicing (100% financed project, 30 years)	$149,800	$132,100	$110,800	$170,600	$153,600	$166,300	$162,900
Project salvage value at Year 50	$0	$0	$0	$0	$0	$0	$0
Total Annual Costs	$172,800	$154,300	$128,800	$196,600	$179,600	$194,300	$195,900
PRESENT WORTH OF PROJECT COSTS	$3,527,000	$3,161,000	$2,646,000	$4,013,000	$3,666,000	$3,989,000	$4,031,000
PROJECT REVENUES / SAVINGS							
Avoided Utility Fuel Costs (50 years)	$106,000	$109,800	$112,000	$113,000	$111,000	$114,000	$115,000
Avoided Fuel Costs from Use of Excess Energy (50 years)	$62,800	$45,600	$7,000	$49,000	$46,000	$50,000	$52,000
Revenue from Environmental Attributes (50 years)	$11,700	$8,400	$4,700	$8,900	$8,500	$9,000	$9,200
Total Annual Savings / Revenues	**$180,400**	**$163,800**	**$124,000**	**$171,000**	**$165,000**	**$173,000**	**$177,000**
PRESENT WORTH OF PROJECT REVENUES / SAVINGS	$4,642,000	$4,215,000	$3,184,000	$4,395,000	$4,254,000	$4,459,000	$4,552,000
BENEFIT TO COST RATIO	**1.32**	**1.33**	**1.20**	**1.10**	**1.16**	**1.12**	**1.13**

Notes:
A real discount rate of 3% is used for the time value of money for all calculations.